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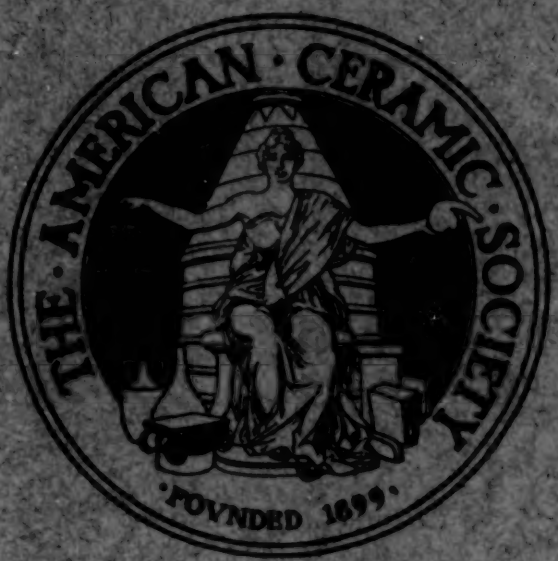

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ABSTRACTS
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THE PHYSICAL PROCESSES OCCURRING IN THE MELTING AND COOLING OF GLASS

By J. T. Littleton

ABSTRACT

The thermal treatment of glass is followed from the melting and refining stage downward through the annealing zone. The fusion of the batch constituents is shown to be completed in a short time and the greater portion of the time required to obtain glass of good quality is used in freeing the glass from gas bubbles and in improving the homogeneity. It is postulated that melting is similar to a diffusion process, the constituents being mixed by diffusion aided by convection currents. A review of the evidence for silicate compounds in glasses shows that only electrical conductivity data indicate the existence of such compounds. Dissolved gases probably assist fining by diffusing into the bubbles and increasing their size. This offers one explanation of the action of fining agents. Devitrification is shown to be avoidable by a knowledge of the devitrification temperature and staying above this temperature during melting and fining. Any subsequent cooling through the devitrification zone should be rapid. The earlier annealing equations are based on the experimental observation that rate of release of stress in glass is proportional to the square of the stress. This fact is difficult to explain on a physical basis when it is assumed that viscosity is constant with temperature. However, data are cited which show that viscosity changes with time and when the instantaneous values of viscosity are used it is shown that the rate of release of stress is proportional to the stress divided by the viscosity. The constant of proportionality has the dimensions of the shear modulus of glass and is equal to one-fourth the value of the shear modulus in glass at room temperature.

I. Introduction

It has been known for some time that the physical properties of silicate glasses are affected by the heat treatment of the test sample. Fortunately most of the changes caused by differences in heat treatment are of a minor magnitude and do not particularly affect the quality of the manufactured product. However, the subject of changes in glasses caused by thermal treatment is of first order importance to the research worker whose prime problem is that of precision in measurement and who is mostly interested in the question of the constitution of glass.

The raw materials entering into inorganic glasses are first mixed together in their proper proportions, then melted, fabricated to some shape, and cooled. It is evident that from the batch stage the entire process of manufacture is one of heat treatment of the raw materials and of the manufactured article. Even after glass has been first formed to one shape it may be reheated and fashioned into something entirely different, or form a part of something else, as illustrated by laboratory apparatus made by the blast burner, vacuum bottles, incandescent lamp bulbs, radio tubes, thermometers, and many other articles. The heat treatment of the glass is an inseparable part of its manufacture. It is proposed to discuss here from the standpoint of the physicist the separate stages of the heat-treating processes and their bearing on the properties of glasses.

II. Melting

(1) Melting Schedule Not Considered

Glasses of many varied compositions are melted commercially and experimentally and of course no one temperature schedule is adequate for all glasses; as a matter of fact even the same glass has a temperature-time-schedule depending upon the design of the melting unit, hence a specific melting schedule can not be a part of this discussion.

(2) Evidence Not Conclusive of Silicate Compounds Formed

It is believed by many that melting consists, first, of a chemical combination of certain of the ingredients and then a fining process, this latter being merely an escapement of entrapped bubbles. Little is known as to the exact chemical combinations taking place in glass during the melting process. The evidence of the existence of silicate compounds existing in solid glass formed does not appear to be very conclusive. The recent paper by Seddon, Tippett, and Turner[1] points out a relation between specific resistance and composition indicating the formation of the compound sodium disilicate. But in general there seems to be very little other evidence of compounds in glass formed during melting and existing at room temperatures. The measurements of physical properties and composition fail to indicate the presence of compounds.

(3) Evidence That Soda and Silica Do Not React Chemically

Howarth, Maskill, and Turner[2] explain the solution of soda in glass as the formation of soda silica compounds on the surface of the silica

[1] S. Seddon, E. J. Tippett, and W. E. S. Turner, *Jour. Soc. Glass Tech.* (*Trans.*), **16**, 450 (1932).

[2] J. T. Howarth, W. Maskill, and W. E. S. Turner, *Jour. Soc. Glass Tech.*, **17**, 25–49 (1933).

grains followed by the gradual solution of the compounds into the silica. At low temperatures the silica grains when first attacked become clouded on their surfaces only but gradually become opalescent. The sodium carbonate is decomposed by the silica, and the sodium oxide penetrates the silica and is absorbed by it, perhaps combining with it in various definite proportions, but this later recombination can not be considered as definitely proved. It may well be that the solution of silica by the soda is merely an absorption process similar to the solution of silica by boric and phosphoric acids. The silica structure of the sand grains is enlarged by the high temperature and consequent molecular activity and is easily penetrated by the smaller soda molecules, thus causing the fluxing effect, but not by a definite combination of elements in definite proportions characteristic of the formation of compounds. The bonds, if formed, are so weak that they are continually disrupted by thermal agitations. Melting then would consist of a fine subdivision of all batch particles and a molecular mixing and diffusion of these particles into a homogeneous mass. If there be no definite chemical compounds as such forming during melting, after the decomposition of the batch, there will be no delayed reactions to be completed, and beyond the effects of degree of homogeneity there will be no effect of the time and temperature of melting on the physical properties of the final product.

(4) Diffusion Rate Owing to the viscosity of the mixture, this mixing is slow yet is initially surprisingly rapid compared to the time required to obtain homogeneous glass by simple diffusion processes after fluxing is complete. Day[3] has shown that approximately 30 minutes at 1500°C is sufficient to form a glass from the raw batch materials which has the final properties of glass melted for much longer times.

Figure 1 shows the results of Day[3] on a soda-lime-glass containing no fining agents. The glass was melted in a platinum crucible in an electric furnace having a particularly uniform temperature distribution tending to eliminate the effects of possible convection currents.

In practice the diffusion process is considerably aided by the liberation of gas from the batch materials. The large gas bubbles in escaping stir or agitate violently the molten glass and in this manner effectively mix the materials. Mixing is also assisted by convection currents.

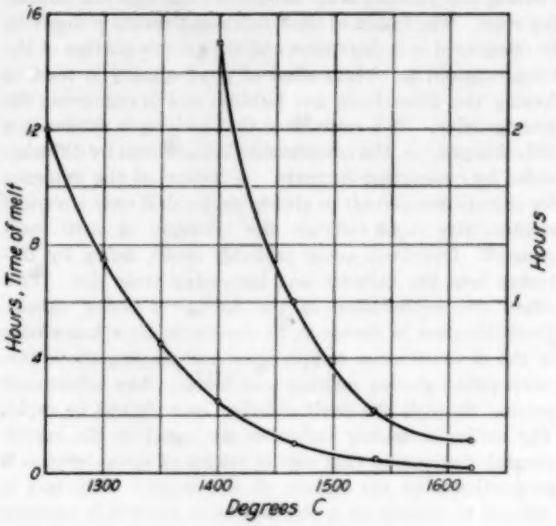


FIG. 1.

Except for convection currents the glass is fairly quiescent after the gas evolution is complete and consequently there is no stirring action to break up the cords which exist for some time.

(5) Properties of Glass Not Affected by Melting Schedule At one time it was believed that the physical properties of glasses were affected by the thermal treatment of the glass in the molten condition.[4] However, later work led to the positive conclusion that the changes in properties observed and ascribed to thermal treatment were due to inhomogeneities and impurities from the dissolved clays of the melting container, causing the formation of a glass of a new composition.

(6) Dissolved Gas Affects Rate of Fining but Not Properties of Glass There is still one other factor depending upon melting conditions which might affect the properties of glass and that is the quantity, character, and disposition of the dissolved gas. Dissolved gas in glass was first analyzed by Shepherd and reported by Allen and Zies.[5] Dalton[6]

[3] R. K. Day (presented at meeting American Ceramic Society, Feb. 24, 1931).

[4] J. T. Littleton, "A Review of Recent Progress in the Study of the Thermal Treatment of Glass," *Jour. Soc. Glass Tech. (Trans.)*, **15**, 262 (1931).

[5] E. T. Allen and E. Zies, *Jour. Amer. Ceram. Soc.*, **1**, 737 (1918).

[6] R. H. Dalton, *ibid.*, **16** [9], 425–32 (1933).

has shown that glass at room temperature may contain practically 100% by volume of dissolved gas. While gas content might have considerable to do with the rate of fining and the action of fining agents, the limited study so far made indicates little effect on the physical properties of glass.

The fining of glass is again largely a physical process. The rate of fining of the glass is controlled by the viscosity of the glass, the size of the bubbles, the action of the dissolved gas, and the direction and magnitude of the convection currents. The gas-forming process during the decomposition of the batch materials is rather quickly completed. The experiments of Day mentioned earlier showed that glass free of speck could be obtained in thirty minutes' time at 1500°C and in ten minutes at 1600°C. This means that any process of gas evolution is finished in somewhat less time than this. The theory that seeds are a product of chemical reactions lasting for hours seems to have no foundation. Dissolved gas stays in solution, possibly at times in a highly supersaturated state, unless there be some mechanical or temperature disturbance. The phenomenon of "reboil" must be a dissolved gas evolution. The exact condition necessary to cause a reboil must depend upon the degree of saturation of the dissolved gas. There has been no investigation made which will connect in a quantitative manner gas content, temperature, and reboil.

Various materials may be added to glasses to assist in fining. The physical and chemical action of glass fining agents are not particularly well understood. The consensus of opinion is that a fining agent is a gas-forming agent. The dissolved gases from the fining agents diffuse into the bubbles and seed in the glass, thus decreasing the amount of dissolved gas as well as increasing the bubble size and consequently lessening the possibility of seed formation.

Salt cake, in addition to its fining action, seems to have a direct action on the silica grains. Sand in a glass batch tends to collect in dry lumps just as does flour in water, and salt cake permeates these lumps, separating the grains and thus exposing each surface of each grain simultaneously to the solution processes.

Convection currents in the glass serve to mix the glass better by their stirring action but they may also serve to retard fining since the downward flow of the glass may exceed the gravity rise of the bubbles and hence sweep the bubbles toward the colder portion of the melt, considerably increasing the time required for fining. The control of convection currents then becomes a problem of temperature distribution and furnace design.

It is therefore concluded that the temperature treatment of glass during melting affects primarily the quality of the glassware obtained but has no observable effect on the physical properties of the glass beyond that of homogeneity.

III. Devitrification

After a glass is melted and fined it is worked to some shape. A cooling process precedes and attends the working process. Below some definite temperature called the devitrification or liquidus temperature the glass will crystallize. If fabrication can be accomplished above the devitrification or liquidus temperature then there is slight danger from devitrification during cooling, since the cooling of the fabricated article is always rapid until the annealing zone is reached. Most glasses will not devitrify in the annealing zone in the time required to anneal.

(1) Devitrification Rate Dietzel[7] has given some information concerning one family of soda-lime-silica glasses. The observations of Dietzel show there is a temperature of maximum crystallization at roughly 100° below the liquidus temperature and below this maximum crystallization temperature the velocity of crystallization is retarded with decreasing temperature and finally becomes zero. For a discussion of Dietzel's measurements in some detail the reader is referred to recent papers by Littleton[4] and Preston.[8]

(2) Viscosity at Liquidus Affects Devitrification Rate Instead of measuring directly the crystallization speeds as did Dietzel, the tendency of a glass to devitrify may also be evaluated by determining the liquidus temperature and possibly the viscosity of the glass at the liquidus. The technique of measuring the devitrification temperature has been developed and adequately described by Morey and his co-workers. The glasses more fluid at the liquidus are more easily devitrified. It is possible that specifying the viscosity at the liquidus rather than temperature, or the ratio

[7] A. Dietzel, *Sprechsaal*, **62**, 506 (1929).
[8] F. W. Preston, *Glass Ind.*, **12**, 1 (1931).

of temperature to viscosity, will give a figure which has some relation to the devitrification tendencies of the glass. In a limited composition field the glass having the highest viscosity at the liquidus temperature should devitrify the most slowly.

The problem of avoiding devitrification is then simply one of determining the liquidus temperature and keeping the glass above this temperature during any protracted heating. Any passage through the devitrification zone should be as rapid as is practical.

In the majority of present-day commercial glasses the subject of devitrification is of little importance. If the present available information as to compositions and the melting and working processes be applied there is little likelihood of devitrification occurring. Devitrification is practically always due to an inhomogeneity in composition. At the particular point of devitrification the glass composition deviates from the average so as to favor crystallization.

The recent comprehensive reviews of the subject of devitrification have treated this subject in considerable detail and it would be mere repetition to consider this question any further in this place.

IV. Annealing

As hot fabricated articles are cooled the glass becomes solid or too viscous to flow or yield in finite time under forces which are insufficient to cause fracture.

Glass in cooling from a molten state may, at the final temperature, be left in a strained or stressed condition. The stresses are caused by a differential contraction of parts of the glass with respect to other portions. If, while the glass is sufficiently fluid, a temperature gradient be introduced in it and, as it cools, this gradient be maintained until it is practically a solid, then as the temperature gradient disappears there will be strain introduced depending upon the temperature distribution at the time the glass becomes solid. Most annealing schedules, however, aim to bring the glass to a condition of uniform temperature before cooling begins and at this temperature to release all the internal stress, then to cool the glass so that no objectionable additional stress will be introduced during cooling. During this cooling there is a temperature gradient introduced and, if there be a yield in the glass due to these temporary stresses, then in the final state as the gradient disappears the amount of strain released by the viscous yield will reappear, but of opposite sign. The physical explanation of strain, its cause, and removal have been described by many others and no repetition of that is needed here.

The glass manufacturer is chiefly interested in the economics of producing ware so annealed that its service will be satisfactory, while the scientist is interested in the exact laws of annealing and in what happens in the glass during this process. It is in this temperature zone that the glass changes from a noticeably fluid body to a solid unyielding substance. It is natural to expect that if its properties in the solid state are affected by a temperature history in some upper temperature level this zone of change to a solid would be the most effective temperature zone in affecting the properties of the glass. Yet in spite of this natural presumption, it has been only in the last fifteen years that the changes in the properties of glasses taking place during the annealing process have been investigated to any considerable extent.

Since the work of Adams and Williamson and of Hampton, it can be stated that so far as the practical annealing of commercial glassware is concerned the problem is simply one of temperature control. Fine annealing of such ware is not required and is even not desirable in many articles. However, in optical ware and large lenses or mirrors it is believed to be necessary. But even in this field there has been no work done which indicates the necessary degree of annealing. Many optical grinders state that if the strain be symmetrical it will give the desired results even though its intensity be high. But besides the mere release of strain during annealing there is a change in the physical constants of glass caused by the prolonged heating. The exact laws of strain release are of more theoretical interest than of practical importance (very large glass objects excepted), since by an understanding of these phenomena we are able to arrive at more definite conclusions as to the constitution of glass. Accordingly the studies of the effects of the thermal treatment of glasses in the annealing zone can be separated into two parts, (1) rate of strain release, and (2) effect of thermal treatment on physical properties. These two divisions are, as will be seen, not entirely separated one from the other.

(1) Rate of Strain Release As mentioned earlier the process of annealing may be separated into two parts, one relieving the stress at constant temperature and the other cooling the glass so that no objectionable stress is introduced. In practice the latter treatment is more difficult to control than the former. Physically, however, it becomes a problem in heat conductivity plus that of strain release, and if the problems of strain release are solved the cooling problem is then capable of solution. Accordingly, only strain release or relaxation laws are discussed here. The equations hitherto developed giving the relationship between strain release and time at any constant temperature are only approximate. As said before they are very satisfactory for ordinary sizes and shapes but are not so satisfactory for larger objects. Most of the present difference of opinion has to do with how the rate of annealing varies with the stress.

If glass be a purely viscous fluid during annealing at constant temperature, then as deduced by Maxwell, $df/dt = kf/\eta$, where f is the stress, η, the viscosity, and k, a constant for the given glass at the given temperature. Adams and Williamson found experimentally that df/dt did not vary as f but as f^2. Existing theories and observations are based on the assumption that viscosity is constant at a constant temperature, that is, does not change with time. Lillie has shown, however, that viscosity does change with time. The time rate of change of viscosity is not a simple affair and the introduction of this factor into annealing equations leads to a fairly complex expression somewhat difficult to handle analytically. However, it must be the failure to take into account this time change of viscosity which has caused the discrepancies between theory and observation.

The change in viscosity with time is an equilibrium-attaining process similar to the changes in expansion coefficient, density, refractive index, specific heat, and electrical conductivity previously observed. Berger[9] has reviewed the data in the recent literature on these effects. Littleton[10] has attempted to show that these changes do not occur at a fixed definite temperature but are changes resisted by the viscosity of the glass; hence at low temperatures they occur very slowly, but as the temperature is increased the changes become sufficiently rapid so that they are observable in the time of the experiment. If the rate of temperature increase be rapid the change will appear to occur suddenly. The measurements have usually been made on the properties of glasses while they were undergoing changes in their equilibrium and there is not much information bearing on the properties of glasses when fully stabilized at different temperatures.

Viscosity at constant temperature changes with time at a rate depending upon both the temperature and the previous thermal history of the test piece. The phenomena behave as though the viscous condition belonging to some previous temperature condition was frozen into the glass and time was required for the glass to change over from its former state of fluidity to that characteristic of the new given temperature. A glass suddenly cooled is initially more fluid, but a glass after being held at one temperature for some time and then having its temperature suddenly increased is initially more viscous. In the first case the glass gradually gets stiffer, and in the second case the glass becomes more fluid as its temperature is held stationary. The curves in Fig. 2 show the magnitude of this change. The newly drawn fiber increases in viscosity by a factor of 10 and the glass previously stabilized at 478° decreases in viscosity by about a factor of 5.

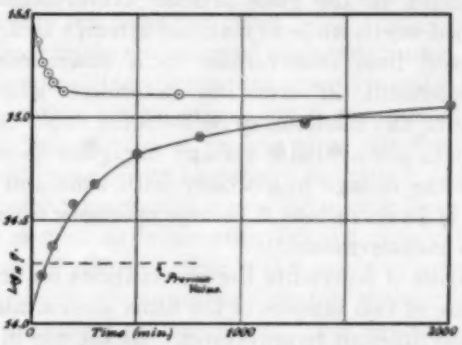


FIG. 2.—Viscosity-time curves for two samples at 480.7°C. The upper curve is for a sample previously treated at 477.8° for 64 hours; the lower curve is for a newly drawn sample (data by H. R. Lillie).

The laws of change of viscosity with time have not been accurately determined. The above curves simply represent the viscosity change with time in the case of a glass initially in some unknown state of equilibrium. This initial state will depend upon the temperature from which the

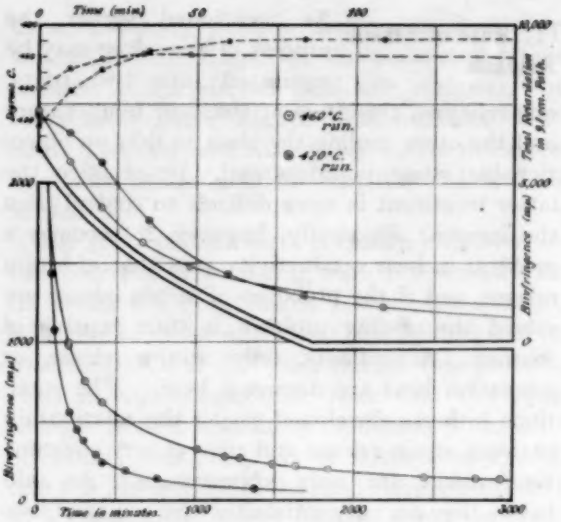
[9] E. Berger, *Jour. Amer. Ceram. Soc.*, **15** [12], 647–77 (1932).
[10] J. T. Littleton, *Ind. Eng. Chem.*, **25**, 748–55 (1933).

glass was cooled and also upon how rapidly it was cooled to its final state. The change of viscosity at constant temperature is then a variable, since the initial state is a variable. This initial state of the glass can be controlled to a degree by careful control of the experimental conditions. In practice, however, the conditions are much more complex. The cooling rate depends upon the dimensions of the article and the local cooling conditions. These conditions vary and can not be duplicated in an experimental sample. In other words, while it is possible to measure accurately the time-viscosity relationship for a series of glass test specimens having known thermal histories it is not possible to identify the thermal history of a glass article with the proper time-viscosity curve so that the changes in viscosity with time can be applied to compute the rate of annealing of the glass article. Nevertheless it seemed worth while to make an attempt to apply viscosity-time observations to a strain release measurement in order to determine whether there be any relationship between the two. Since no data are available on any one glass showing both the change in viscosity with time and the rate of strain release, it became necessary to make such measurements.[11]

Figure 3 represents the observations on strain release of two samples of the same glass annealed at two different temperatures. At the top of the figure is given the temperature schedule and the initial strain release data plotted on an enlarged scale.

It is evident from Fig. 4 that the rate of change of stress is proportional to the square of the stress in accord with the Adams and Williamson equation.

In order to evaluate the instantaneous viscosity of the glasses, it was necessary that the viscosity measurement follow the temperature schedule of the annealing test. Accordingly the viscosity test specimen was inserted in a furnace having its temperature the same as that of the annealing temperature furnace at the start of the

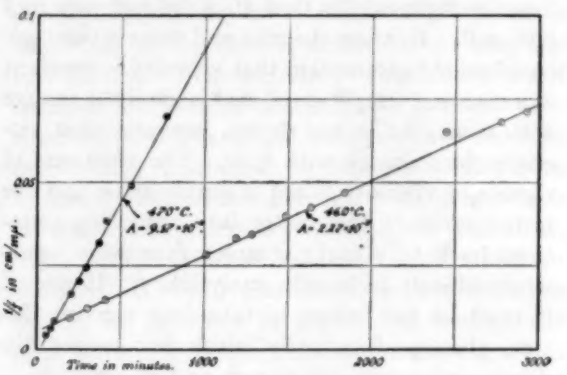


Strain release in Oil chilled Lime Glass.

FIG. 3.

annealing run and the temperature was increased at the same rate.

Figure 5 represents the viscosity change with time of the glass at the two temperatures. Since in the annealing test the temperature did not reach its final value until about forty minutes the



Strain Release in Lime Glass.

FIG. 4.

same procedure was followed in the viscosity run. The enlarged scale in the upper left hand corner of Fig. 5 shows the change in viscosity during the changing temperature interval. The lower curves are all at practically constant temperature.

From the curves in Fig. 5, η is obtained for different times. In Fig. 6 the log f/η is plotted against the log of df/dt. It is seen that this relationship is fairly linear. However, in order

[11] The author of this paper gratefully acknowledges the assistance of H. R. Lillie of this laboratory who has furnished the new data used in this discussion. The experimental procedure was identical with the methods for measuring low-temperature viscosities used and previously reported by Lillie in *Jour. Amer. Ceram. Soc.*, **14** [7], 502 (1931). The strain release measurements were made using the usual calibrated quartz wedges. His new work on viscosity-time relations has just been published in *Jour. Amer. Ceram. Soc.*, **16** [12], 619 (1933).

to allow for the time required for the annealing specimen to come to constant temperature the zero time of the viscosity run was taken thirty

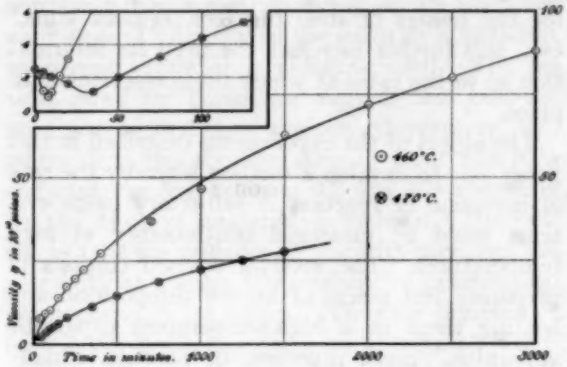


FIG. 5.

minutes ahead of the annealing time, zero. The slope of the curve is unity, consequently the equation of the graph is

$$-df/dt = 6.7 \times 10^{10} f/\eta$$

The constant, 6.7 times 10^{10}, has the dimensions of an elasticity coefficient. For glass the shear

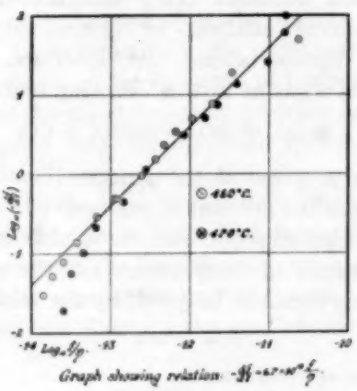


FIG. 6.

modulus at room temperature is roughly 2.8 times 10^{11} which is greater than 6.7 times 10^{10} by a factor of 4. Numerically then

$$-df/dt = Gf/4\eta$$

where G is the shear modulus of the glass at room temperature. Just what G is at the annealing temperature is hard to say, but it is not probable that it is as small as one-fourth the room-temperature value.

This equation for the rate of annealing of glass is physically understandable but not simple to apply.

It is apparent that probably df/dt does vary as f/η. The inability to get a better experimental verification of this conclusion is no doubt due to the inability to identify the proper viscosity change curve to apply to the strain release sample. Very probably there can be no proper viscosity curve to apply to such a sample. The viscosity of the viscosity test specimen, a small glass fiber millimeter in diameter, is probably fairly homogeneous throughout the sample, while in the annealing test piece the viscosity probably varies from the surface inward, since the cooling rates of these portions of the glass varied considerably one from the other.

Accordingly one is forced to the conclusion that while annealing phenomena obey viscosity laws in a rather simple manner it is not possible to apply viscosity data to annealing laws so that annealing rates can be exactly computed. If the viscosity-temperature curve for a glass be available as well as information on the time rate of change of viscosity, then it is possible to compute an approximate annealing schedule without making annealing measurements. For practical results, however, the Adams and Williamson empirical equation that rate of release of stress is proportional to the square of the stress is satisfactory and convenient to use. For high and low stresses this law is not true, but an empirical correction can be applied for those conditions where further refinement is necessary. For the best results an annealing rate curve should be obtained for the glass in question at the temperature at which the glass is to be annealed.

There has been considerable doubt as to what effect viscosity has on annealing. It has even been questioned whether it has any effect. These results seem to show conclusively that annealing of glass is a viscous flow phenomenon, the rate of release of stress for unit stress being inversely proportional to the viscosity.

CORNING GLASS WORKS
CORNING, NEW YORK

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THE MEASUREMENT OF REACTION RATES AT HIGH TEMPERATURES*

By J. H. Chesters and C. W. Parmelee

ABSTRACT

Cylindrical test pieces, rammed under a pressure of 10,000 pounds per square inch, were heated to temperatures varying between 1300°C and 1500°C. The rate of inversion of quartz to cristobalite and the rate of spinel formation in mixtures of electrically fused magnesia and alumina were determined from the slope of the expansion curve at constant temperature. The amount of cristobalite or spinel formed was calculated from the density determinations before and after firing. The products were identified by X-ray and microscopic investigation.

Unfired silica brick showed almost complete inversion to cristobalite after two hours at 1500°C, the corresponding vertical expansion being about 6%. The addition of 2% CaO to unfired quartzite was found to increase the rate of inversion to cristobalite quite appreciably. A further addition of 1.5% Na_2O + 1.5% Fe_2O_3 so increased the rate of inversion at 1400° that after two hours only cristobalite appeared to be present.

A mixture of electrically fused magnesia (0.15 to 0.06 millimeter grain size) and alumina (3.59 to 0.15 millimeter grain size) was found to contain about 25% spinel after two hours at 1500°C. The addition of 2% B_2O_3 increased the amount of spinel formed under similar conditions to 75%. Test pieces made solely from magnesia and alumina of one grain size (0.06 millimeter) showed complete conversion to spinel after only ten minutes at 1450°C. The sensitivity of this method of studying reaction rates is such that an expansion of one scale division is equivalent to the formation of 0.1% of spinel.

I. Introduction

Although a great deal is known concerning equilibrium conditions in refractory oxide systems, comparatively little has been written on the rate at which equilibrium is attained. It is known, for example, that when magnesia and alumina are heated together in molecular proportions the product is spinel, but very little is known about the influence of temperature, mineralizers, grain size, etc., on the rate at which this reaction proceeds.

In dealing with refractory materials nonequilibrium conditions, in general, are being considered. A silica brick, even if well fired, often contains a considerable amount of quartz and will continue to invert to cristobalite and tridymite during use. Similarly, fire brick or porcelain show varying degrees of mullite formation according to the heat treatment they have received. The increasing use of unfired brick for the linings of steel furnaces, cement kilns, etc., still further increases the need for information as to the rates at which these reactions take place.

The object of the experiments described in this paper was to develop a method whereby the rate of inversion or reaction in refractory oxide systems could be measured continuously at high temperatures. The method devised consists in preparing test pieces of known composition and heating them in a high-temperature expansion apparatus. Since inversion or reaction usually takes place with an appreciable volume change it is possible to study the rate of change by observing the slope of the expansion curve at constant temperature.

II. Literature

(1) Reactions in the Solid State

Eitel[2] discusses several methods of studying solid-state reactions. One method consists in preparing pastilles which can be heated in contact with one another, the extent of the reaction which occurred being determined by the microchemical analysis of layers taken from various depths behind the interface. If one product is a gas as in the following reaction:

$$BaCO_3 + SiO_2 = BaSiO_3 + CO_2$$

then the progress of the reaction can be determined from the amount of gas evolved. Thermal curves, color changes, etc., have also been used. The influence of temperature on the above reaction was found to be given by the relation

$$v = ce^{-k/T}$$

Where v = reaction rate.
T = absolute temperature.
c and k = constants.
e = exponential constant (2.718)

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* Presented at the Annual Meeting, American Ceramic Society, Cincinnati, Ohio, February, 1934 (Refractories Division). Received December 14, 1933.

[1] (*a*) A. E. Fitzgerald, "New Developments in Unfired Magnesia Brick for the Metallurgical Industry," *Mining & Met.*, **12** [300], 527–32 (1931), and *Ceram. Abs.*, **11** [4], 248 (1932); *Metals & Alloys*, **3**, 25 (1932) and *Ceram. Abs.*, **11** [7], 416 (1932); *Pit & Quarry*, **24**, 38 (1932); *Blast Fur. Steel Plant*, **20** [8], 658–60 (1932) and *Ceram. Abs.*, **11** [10], 531 (1932).

(*b*) J. H. Chesters and W. J. Rees, "Use of Unfired Brick for Linings of Induction Furnaces," *Trans. Ceram. Soc.* [Eng.], **31** [7], 243 (1932); *Ceram. Abs.*, **11** [11], 575 (1932).

[2] W. Eitel, Physikalische Chemie der Silikate, Leipzig, 1929.

The reaction speed was also found to vary inversely as the square of the grain size.

Just as melting requires a certain minimum displacement of the particles in the lattice, so reaction between materials only occurs when the amplitude of vibration of the particles is sufficient to permit interchange (Platzwechsel). The results given by Tammann[3] suggest that reaction does not occur below a given temperature, nT, where T is the absolute melting point and n, a constant varying between 0.3 and 0.9 according to the type of material considered. Hedvall[4] shows that the presence of impurity increases the reactivity at a given temperature by loosening up (Auflöckerung) the lattice. Thus the presence of only 0.1% $BaCl_2$ has quite an appreciable influence on the rate of reaction between barium oxide and lead chloride. Jander and Stamm[5] have studied the interchanges which occur when various spinel pastilles, *e.g.*, $MgAl_2O_4$ and $MgCr_2O_4$, are heated in contact. The results suggest that reaction occurs at temperatures well below those at which a liquid phase appears.

(2) The Silica Inversions Sosman[6] discusses the literature on the inversion of quartz to cristobalite and tridymite. Although tridymite is the stable modification in the temperature range 870 to 1470°C it is apparently only formed after the quartz has first inverted to cristobalite. No systematic study has been made on the influence of temperature on the rate of inversion, but such evidence as is available suggests that the inversion speed increases logarithmically with rising temperature. Inversion tends to begin at the surface of the grains. This is clearly seen in fired silica brick, where the residual cores of the larger grains are surrounded by a shell of cristobalite and tridymite.

Salmang and Wentz[7] have studied the influence of firing temperature on small cylinders made from quartzite + 2% CaO + 1.5% Fe_2O_3 + 1.5% Na_2O. As the firing temperature was raised from 1050 to 1425°, the permanent expansion increased from 2.98 to 5.50%. The maximum cold strength was shown by the test piece fired at 1050°, suggesting that the bond had already become effective at this temperature. A test piece heated for twenty-four hours at 1425° was found to have inverted almost completely to tridymite.

(3) Spinel Most of the literature on spinel refers to the preparation of relatively pure materials by heating together the finely divided oxides, either with or without a flux. It is not surprising that spinel formation under such conditions took place with a bulk shrinkage. Thus Rieke and Blicke[8] used materials which yielded a body of about 50% porosity, even after shrinking considerably during firing. Assuming the values 3.56 and 3.94 for the density of magnesia and alumina, respectively, and the value 3.58 for spinel it can be shown that the reaction between magnesia and alumina (yielding spinel) should take place with a volume expansion of 6.86%. This calculation is based on the assumption that both the initial and final bodies have zero porosity. The results obtained in this paper show that the porosity tends to increase during firing, and hence the actual expansion measured is much greater than that given above.

Rieke and Blicke suggest that some reaction causing sintering occurs at temperatures as low as 900°. In the presence of boric acid the reaction rate increases considerably, the amount of spinel formed in a given time at 1200° increasing from 40 to 74% with a 2% addition of boric acid.

NOTE: The value 3.58 was calculated from the lattice distance 8.06 given by Hauptmann and Novak,[9] and subsequently confirmed in this laboratory. It is in agreement with the experimentally determined value given by Rinne[10] for synthetic spinel.

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[3] G. Tammann, *Z. anorg. allgem. Chem.*, **149**, 77 (1925).

[4] J. A. Hedvall, "Capability of Reacting in the Solid State and Its Dependence on Factors of Loosening Up," *Z. angew. Chem.*, **44**, 781–96 (1931); *Ceram. Abs.*, **11** [8], 470 (1932).

[5] W. Jander and W. Stamm, "Internal Structure of Solid Oxygen-Containing Salts at High Temperatures. III, Electrical Conductivity, Diffusivity, and Reactivity of Spinels in Solid State," *Z. anorg. allgem. Chem.*, **199** [1], 165–82 (1931); *Ceram. Abs.*, **11** [4], 268 (1932).

[6] R. B. Sosman, Properties of Silica. The Chemical Catalogue Co., 1927; *Ceram. Abs.*, **7** [7], 505 (1928).

[7] H. Salmang and R. Wentz, "Production of Tridymite Brick, II," *Ber. deut. keram. Ges.*, **14** [4], 141–55 (1933); *Ceram. Abs.*, **12** [9], 331 (1933).

[8] R. Rieke and K. Blicke, "Development, Properties, and Technical Use of Some Spinels," *Ber. deut. keram. Ges.*, **12** [4], 163 (1931); *Ceram. Abs.*, **10** [10], 704 (1931).

[9] H. Hauptmann and J. Novak, "Lattice Constants of Compounds of Spinel Type," *Z. physik. Chem.*, **B15**, 372 (1932); *Ceram. Abs.*, **11** [12], 617 (1932).

[10] F. Rinne, N.J.B.B., LVIII, Abt. A, p. 43 (reference in *Ber. deut. keram. Ges.*, **12**, 168 (1931).

III. Experimental Procedure

(A) Raw Materials

(1) Unfired Silica Brick The material used in the preliminary tests on the rate of inversion of quartz to cristobalite was a commercial unfired silica brick having the grading given in Table I, column (1).

TABLE I

SIEVE ANALYSES ON SILICA

Tyler mesh	(1) Unfired silica brick (%)	(2) Medina quartzite (%)
On 8	23	..
8–28	26	45
28–65	20	10
65–150	14	26
Through 150	17	19
	100	100

The dry material showed an ignition loss of 1.72%, while the chemical analysis of the calcined material is as follows

	(%)
Silica	96.32
Alumina	0.83
Iron oxide	0.67
Lime	2.00
Magnesia	0.06
	99.88

(2) Medina Quartzite A sample of Medina quartzite was crushed, sieved into sections, and recombined to give the grading shown in Table I, column (2).

(3) Electrically Fused Magnesia The electrically fused magnesia was received in eight different grain-size groups varying between 3.59 and 0.06 millimeters. These were recombined to give a particular grain distribution referred to in this paper as "grade X" (see Table II, column (1)). The material was said to be 95% magnesia.

TABLE II

GRAIN-SIZE DISTRIBUTION

Approximate grain size (mm.)	(1) Magnesia or alumina "grade X" (%)	(2) Spinel mix. Magnesia (%)	Alumina (%)
3.59	15		15
1.79	15		15
1.06	15		15
0.55	10		10
0.20	10		10
0.15	10	3.4	6.6
0.09	10	10.0	
0.06	15	15.0	
	100	28.4	71.6

(4) Electrically Fused Alumina The electrically fused alumina, said to be 99.5% Al_2O_3, was received in similar grain-size groups and was recombined to give the "grade X" type of grading.

(5) Mixtures for Preparation of Spinel To prepare spinel, the magnesia and alumina were mixed in the ratio 28.4 to 71.6 by weight, the magnesia being added as material of 0.15 to 0.06 millimeter grain size. The grain-size distribution of the batch is shown in Table II, column (2).

(B) Preparation of the Test Pieces

The test piece used was a cylinder 1.5 inches in height and about 0.88 inch in diameter. High ramming pressures, *viz.*, 10,000 pounds per square inch applied for thirty seconds, were found necessary in obtaining strong test pieces from coarse nonplastic materials like alumina and magnesia. A special mold was designed for work with these highly abrasive materials. It was made in two sections so that it could be taken apart if the plunger seized. The two halves were held together by a heavy steel collar, the exterior of the mold and the interior of the collar being tapered to facilitate separation. In the first series of tests on silica, the test pieces were rammed using a single plunger. In the second series on spinel, two plungers were used in order to produce a more homogeneous test piece. A hole was formed in one end of the test piece by means of a lug screwed into the top plunger. All of the silica test pieces were made with an addition of 5% water. Spinel mix test pieces rammed with water alone were very friable. An addition of gum arabic (1% of the test-piece weight) was therefore made to the water used in moistening the batch.

(C) Preliminary Measurements on the Test Piece

The rammed test pieces were dried at room temperature for one day, heated at 110° for an hour, and then desiccated until required for testing. The diameter of the test piece at the top, middle, and bottom was measured in two directions at right angles by means of a micrometer screw gage. The average value showed great constancy, rarely varying by more than 0.002 inch. The height of the test piece was measured by standing it on a platform, placing a

steel disk on the top, and measuring the distance between the top of the steel disk and the platform by means of an Ames dial device. The initial length could thus be determined to within about $^1/_{1000}$ inch. The volume of the test piece was determined by immersing in mercury in a calibrated volumeter. The density of the raw material was determined in duplicate using two twenty-five cubic centimeter pycnometers and samples of about four to six grams. The flasks were filled *in vacuo* with water at 45°. In general the results on the two pycnometers checked within 0.002. Very hard materials, such as the fused alumina, were ground in an iron mortar to pass 100-mesh and then freed from iron by means of a magnet.

(D) The Expansion Apparatus

(1) The Furnace The furnace used in these tests was the molybdenum wire-wound furnace used in the earlier work on the firing of magnesite brick.[11]

NOTE: The furnace has completed about fifty "runs" and shows no sign of deterioration. The construction of an open-ended molybdenum wire-wound furnace presents two problems as follows: (*a*) the tube must be essentially nonpermeable to gases at the working temperature, and (*b*) nonrigid gas-tight joints must be made between the tube and the steel case.

To meet these requirements heavy castings were welded on to the end plates of the furnace. These were drilled to take the porcelain tube with a clearance of about $^1/_{16}$ inch. The inner edge of the outside face of the casting was further cut away to permit the fitting of the end plates. When the tube was placed in position, the space between the bevelled edge of the end plate and the base plate formed a closed ring, which could be packed with asbestos. By tightening the nuts, the asbestos was forced into contact with the tube and the steel plate, thus forming an essentially gas-tight, but nonrigid, joint. The porcelain tube was surrounded by a 3-inch alundum tube (internal diameter), the space between this outer tube and the steel case being packed with magnesia insulation.

The porcelain tubes were made from a batch of the following composition:

Alundum (R.A. No. 563)	3200 grams
"91" feldspar (Tenn.)	1600 "
Tenn. ball clay	720 "
N. C. kaolin (Spruce Pine)	800 "
N. C. kaolin	800 "
Fla. kaolin	800 "
Sodium carbonate	16 "
Sodium silicate (conc. solution)	19 cubic centimeters
Water (35% of dry batch weight)	

[11] J. H. Chesters and C. W. Parmelee, "The Firing of Magnesite Brick," *Trans. Ceram. Soc.* [Eng.], **32** [8], 349–70 (1933); for drawing showing the test furnace see p. 360.

The clay constituents were ground with water in a porcelain-lined ball mill for about 12 hours. The alundum and feldspar were then added and the batch was reground. The tubes were cast in a plaster mold, a shrinkage of 15% being allowed for drying and firing. The center 6 inches of the tube were grooved to take the half-millimeter winding, 7 grooves per inch. The tubes were dried slowly, suspended from the lid of a refractory sagger and fired at 1550° for about 3 hours.

Cylinder hydrogen was used in all the tests, no precautions being taken to ensure its purity. The hydrogen was led into the furnace via steel tubes welded into the end plates at a point between the two refractory tubes. Two alundum rings were used to cut down the heating of the end plates by shutting off the radiation from the winding.

(2) The Expansion System The expansion system used in the earlier work on magnesite had the disadvantage of being unsymmetrical. The vertical strains could be eliminated by applying a suitable tension to the expansion head, but a twisting moment still remained and distortion occurred after prolonged use at high temperatures.

The system used in these tests was also a differential system, but the two members, instead of being side by side, were concentric. The fixed member was a 1.2-inch alundum tube, *A* (internal diameter). (See Fig. 1.) Slots were cut on either side of the central portion of the tube so that an alundum platform, *B*, could be introduced to hold the test piece. As before, the test piece was separated from the platform and the moving rod, *C*, by means of platinum washers, *D*–*D*. The outer tube was rigidly held in a heavy brass head, *E*. The moving rod, *C*, was fitted with a stainless steel cap, *F*, which slid smoothly in the hole in the brass head. Stainless steel was chosen because of its low expansion coefficient which prevented the cap seizing in the brass head due to unequal heating. An Ames dial was rigidly attached to the brass head, the moving member pressing vertically against the center of the cap, *F*. The dial, which

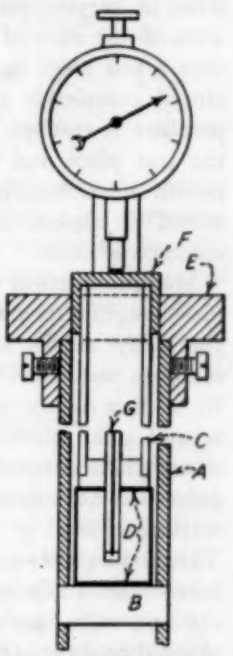

FIG. 1.—High temperature expansion system.

read to $^1/_{10,000}$ inch was calibrated by means of Johansson blocks and showed no serious irregularities.

The stress at the weakest point in the system was reduced to a minimum by calculating the approximate strains set up and then applying a tension to the head sufficient to reduce the strain at this point to zero. In spite of these precautions some distortion was noticed after twenty tests. A calibrated thermocouple (Pt Pt-Rh) was introduced through slots cut near the tops of both the inner and outer tubes and passed via an alundum sheath into the hole in the test piece.

(3) The Test The measured test piece was placed in position, and the expansion apparatus lowered into the furnace, the main weight of the system being taken off the base by means of a pulley and counter-weight. The furnace was heated according to a fixed time-ampere schedule, essentially similar rates of heating being used in all the tests. The actual heating rate used was very high, about 25° per minute, since it was desired to obtain the inversion or reaction rates at particular temperatures and not the more complicated summation of a series of varying rates at different temperatures. Thus if the rate of reaction at 1400° is high, then a test piece heated slowly to 1450° may be almost completely transformed before this temperature is reached. Moreover the smallness of the test piece and the even heating conditions permit a much more rapid rate of heating than would be reasonable with a full-size brick in a commercial kiln.

Measurements of the temperature and the test-piece length were made every five minutes during the early stages of the run. The expansion readings were corrected for the differential effect by adding on the expansion of alundum, and a second small correction for a permanent subsidence which occurred even when an alundum test piece was used and which was attributed to the settling down of the platinum washers, etc. Three hours after starting and approximately two hours after attaining the maximum temperature, the amperage was reduced and the furnace was allowed to cool. On the following day, when the apparatus had cooled to room temperature, the final readings were made and the test piece was removed for re-measurement. One-half of the test piece was used in the density determination and the other half was saved or used in preparing a section for microscopic examination.

IV. Results

(A) Unfired Silica Brick

The influence of temperature on the rate of inversion of quartz to cristobalite was studied by preparing test pieces of crushed and re-rammed unfired silica brick and heating them to 1500°, 1450°, 140 °, and 1300°, respectively. The expansion curves obtained are shown in Fig. 2.

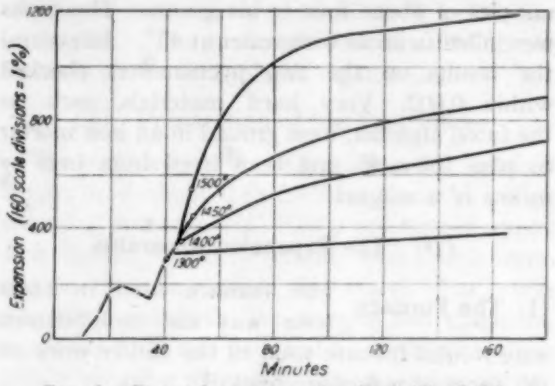

FIG. 2.—Expansion curves of unfired silica brick.

The initial rapid expansion below 600° is due to the reversible alpha-beta quartz change. This is followed by a considerable shrinkage which reaches a maximum at about 1100°. Quartz is known to have a negative expansion above 600°, but the contraction observed is too great to be explained in this way. The contraction is therefore presumably due to the reaction of the lime bond with the silica and the impurities present. This suggestion of flux development at relatively low temperatures is supported by Salmang's observation that the maximum cold strength of a series of brick fired at temperatures varying between 1050° and 1425° was shown by the brick fired at 1050°. Above 1100° the curve changed rapidly from contraction to expansion, the beta quartz to cristobalite inversion having begun. The maximum rate of expansion occurred for a few minutes before and after reaching the maximum temperature. The test piece, heated to 1500°, showed a rapid initial expansion rate, which fell off considerably within a few minutes after reaching the maximum temperature. The general type of the expansion curve is given by the equation

$$y = C - e^{-t}$$

Where y = amount of expansion
t = minutes after reaching max. temp.
C = a constant equal to final expansion value
e = exponential constant (2.718)

TABLE III

TEST RESULTS ON SILICA

Test piece	Material	Firing temperature (°C)	Density (1)	Density (2)	Bulk density (1)	Bulk density (2)	Porosity (1)	Porosity (2)	Expansion l	Expansion d	Expansion $2d + l$	Cristobalite (%)
1	Unfired silica brick	1500	2.63	2.34	1.93	1.55	27.0	34.0	7.0	8.0	23.0	95
3	" " "	1450	2.63	2.36	1.92	1.63	27.0	31.0	4.9	5.7	16.3	85
2	" " "	1400	2.63	2.39	1.95	1.72	25.5	28.0	3.8	4.4	12.6	75
4	" " "	1300	2.63	2.49	1.96	1.83	25.5	26.5	2.0	2.3	6.6	45
6	Medina quartzite (unbonded)	1400	2.65	2.50	1.93	1.77	27.5	29.0	2.3	3.3	8.9	45
7	Medina quartzite + 2% CaO	1400	2.65	2.45	1.95	1.74	26.5	29.0	3.1	3.6	10.3	60
8	Medina quartzite + 2% CaO + 1.5% Na_2O + 1.5% Fe_2O_3	1400	2.67	2.34	1.98	1.63	26.0	30.5	5.7	7.8	21.3	95

The first part of the 1500° curve fits this equation quite closely, but the last part requires a somewhat higher value of C. The low rate of expansion toward the end of the test suggests that the conversion of the quartz to cristobalite is about complete. The data given in Table III show that this is essentially the case, the density having fallen from 2.63 to 2.34. Assuming the value 2.32 for cristobalite, this is equivalent to about 95% inversion. The values given for the amount of cristobalite formed are only approximate, no corrections having been made for the formation of a lime silicate glass, etc. The bulk density showed a similar drop, 1.93 to 1.55, while the porosity increased from 27 to 34%. It is this rise in porosity that accounts for the fact that the observed expansions are much greater than would be expected for a change of density of this order.

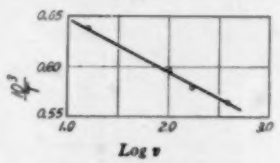

FIG. 3.—Influence of temperature on firing-expansion rate of unfired silica brick.

The curves for 1450° and 1400° are similar, but show much slower initial expansion speeds. At 1300° the expansion is much slower, but constant throughout the test. The linear expansion results and the sum of the horizontal and vertical expansions ($2d + l$) show an obvious correlation with the fall in density. The initial rate of expansion was so influenced by the temperature that an attempt was made to relate the two quantities by means of an equation. Since the expansion rate is a measure of the inversion rate, and since inversion like chemical reaction depends on the degree of displacement of the particles in the lattice it seemed reasonable to try applying the equation

$$v = c \cdot e^{-a/T}$$

given for the solid state reaction be[illegible] barium carbonate and silica. It can be seen from Table IV and Fig. 3 that, although the initial expansion rates varied between 393 and 16 divisions in the first twenty minutes, the relation between log v and $10^3/T$ is essentially linear. If on the other hand the expansion rate is plotted directly against the temperature the result is a curve whose slope increases rapidly as the temperature rises.

TABLE IV

INFLUENCE OF TEMPERATURE ON RATE OF EXPANSION

Test piece No.	Absolute temperature	$1/T \times 10^3$	Expansion in first 20 min., v	Log v
1	1774	0.564	393	2.594
3	1727	0.579	170	2.230
2	1682	0.595	102	2.009
4	1566	0.639	16	1.204

It would be unreasonable to equate the rate of expansion directly with the rate of inversion, since other factors such as increasing porosity enter in, but it would seem clear that the initial rate of inversion in a silica brick batch depends on the temperature in much the same way as do certain reactions in the solid state.

(B) Medina Quartzite

To test the influence of the bond on the behavior of the quartzite, three test pieces (*a*) unbonded, (*b*) with 2% CaO, and (*c*) with 2% CaO + 1.5% Na_2O + 1.5% Fe_2O_3 were heated to 1400°. Neither the unbonded nor the lime-bonded quartzite showed the shrinkage above 600°, which was so marked with the unfired silica brick. The lime-soda-ferric oxide bonded quartzite, however, showed a marked shrinkage at this stage, supporting the suggestion that this shrinkage is due to the formation of a flux.

Both the expansion curve (Fig. 4, curve 2) and the density and bulk density determinations sug-

gest that the addition of 2% CaO increased the initial inversion speed, while the addition of the complex bond, suggested by Salmang, produced

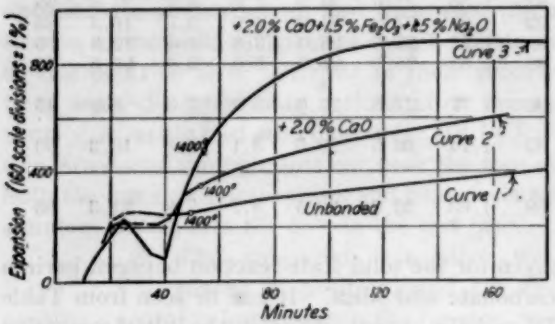

FIG. 4.—Medina quartzite.

as much inversion in two hours at 1400° as the unfired silica brick showed after two hours at 1500°.

(1) X-Ray and Microscopic Examination The fall in density indicates the extent of the inversion but it does not show the nature of the products. X-ray samples were therefore prepared by grinding the material to pass a 240-mesh sieve. These were placed in glass tubes of 0.6-millimeter diameter which were set in the cameras of a multiple X-ray diffraction apparatus of the type made by the General Electric Company. A molybdenum target was used, and exposures varied from 24 to 48 hours. A comparison of the photographs obtained with those of raw quartz, and also with the published photographs of G. L. Clark and H. V. Anderson[12] and E. W. Washburn and L. Navias[13] show that the unfired silica brick inverted almost completely to cristobalite after heating for two hours at 1500°. The 1450° and 1400° samples also showed a great deal of cristobalite, together with residual quartz. The test piece with the lime-soda-ferric oxide bond did not show tridymite, as at first expected, but cristobalite. This result, however, is not in conflict with the results obtained by Salmang, since Salmang's samples were heated for twenty hours as compared with the two hours used in this test.

[12] G. L. Clark and H. V. Anderson, "X-Ray Study of Zonal Structure of Silica Brick from Roof of a Basic Open-Hearth Furnace," *Ind. Eng. Chem.*, **21** [8], 781–85 (1929); *Ceram. Abs.*, **9** [5], 355 (1930).

[13] E. W. Washburn and Louis Navias, "Products of Calcination of Flint and Chalcedony," *Jour. Amer. Ceram. Soc.*, **5** [9], 565–85 (1922); p. 582.

(C) Spinels

The first test piece, made from a batch of the type given in Table II, column (2), showed a decrease in density of 3.83 to 3.77 after two hours at 1500°. Calculation shows that this is equivalent to the formation of about 25% of spinel. The corresponding vertical expansion was small and made accurate measurement difficult. To speed up the reaction without altering the type of grading used, 2% B_2O_3 was added. On firing to 1510° quite rapid expansion set in (Fig. 5) and the density fell from 3.83 to 3.64, equivalent to about 75% spinel formation. The expansion curve was typical of a reaction which begins rapidly and then gradually slows off as completion is approached. Similar tests were made at 1475°, 1450°, 1400°, and 1300°. The results obtained are given in Table V, and Fig. 5. Certain of the curves show a greater rate of expansion toward

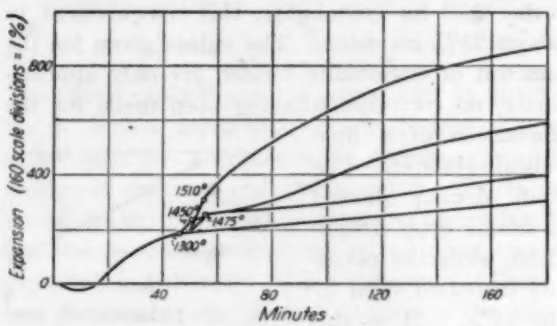

FIG. 5.—Firing expansion curves; spinel mixture 2% B_2O_3.

the end of the two-hour period than after one hour. The explanation of this is that the curve is the product of two processes, (*a*) the expansion due to spinel formation and (*b*) the firing shrinkage, which would occur if no reaction took place. To estimate the amount of this second process tests were carried out on fused alumina and fused magnesia bonded with 2% B_2O_3. Both test pieces were fired at 1450°. The curve for magnesia showed an initial thermal expansion followed by a considerable firing shrinkage. The curve for alumina was essentially similar, but showed a greater initial expansion than was expected for alumina alone. Table V shows that the fired test piece had expanded both vertically and horizontally while the bulk density had decreased and the powder density had fallen from 3.94 to 3.87. Previous tests on fused alumina, without added bond, had shown no such fall in

TABLE V

TEST RESULTS ON SPINEL*

Test piece	Material	Firing temperature (°C)	Density (1)	Density (2)	Bulk density (1)	Bulk density (2)	Porosity (1)	Porosity (2)	Expansion l	Expansion d	$(2d+l)$	Spinel (vol. %)
17	Spinel mix (grade X + 2% B_2O_3)	1510	3.83	3.64	2.94	2.26	23.5	38.0	6.2	13.2	32.6	75
21	"	1475	3.83	3.66	2.84	2.24	26.0	38.5	3.8	11.7	27.2	70
20	"	1450	3.83	3.66	2.77	2.28	27.5	37.5	2.6	9.3	21.2	70
19	"	1400	3.83	3.69	2.81	2.44	26.5	34.0	1.9	7.1	16.1	55
18	"	1300	3.83	3.75	2.85	2.68	25.5	28.5	1.4	2.5	6.4	30
23	Magnesia (grade X + 2% B_2O_3)	1450	3.56	3.53	2.67	2.73	25.0	22.5	−1.7	−2.1	−5.8	..
25	Alumina (grade X + 2% B_2O_3)	1450	3.94	3.87	2.92	2.85	26.0	26.5	0.3	0.5	1.3	..
14	Spinel mix (grade X, no B_2O_3)	1500	3.83	3.77	2.78	2.59	27.5	31.5	0.5	2.8	6.1	25
15	Spinel mix (grade X—Austrian magnesite)	1500	3.82	3.71	2.84	2.51	25.5	32.5	1.7	5.9	13.6	50
26	Spinel mix(all 0.15 mm. + 2% B_2O_3)	1450	3.83	3.52	2.14	1.50	44.0	57.5	9.4	13.0	35.5	100
27	Spinel mix (all 0.06 mm. + 2% B_2O_3)	1450	3.83	3.52	2.13	1.63	44.5	53.5	5.4	10.6	26.7	100

* (1) and (2) Table V indicate readings before and after firing.

density. Reaction of some sort must have occurred. X-ray photographs were taken of fused alumina, both with and without the boric acid bond. The general appearance of the diffraction patterns suggested that the boric-acid bonded material had undergone an extension of the lattice. Further examination shows that the displacement of the lines is not greater than might be due to experimental variations since the alumina lines, being due to such large crystals, are very ragged. Further investigation, using larger quantities of boric acid, would be necessary before it could be shown with any certainty whether solid solution had occurred. No extra lines were found in the photograph of the boric-acid bonded alumina, so if chemical action did occur the product was either a glass or present in such small amounts that it was not detectable by ordinary X-ray examination.

To demonstrate the expansion due to spinel formation only, the expansion curve obtained must be corrected by subtracting the parts due to thermal expansion and firing shrinkage. An attempt was made to do this with the sample fired to 1450°. The curves for alumina and magnesia were combined in the ratio of 0.7 to 0.3. This ratio was chosen because it is approximately the ratio of the volumes of alumina and magnesia in the unfired test piece. In determining the volume of a particular constituent in a body by making traverses with a microscope across a thin section, it is assumed that the percentage, by volume, of the constituent is proportional to the percentage of its intercepts. Since linear thermal expansion will depend on the ratio of magnesia and alumina intercepts along the line of expansion, it seems reasonable to assume that the thermal expansion of a mixture will likewise depend on the volume percentage of the constituents present. If the curve obtained by adding the magnesia and alumina curves in the above ratio is subtracted from that of a spinel mixture at the same temperature the result is a curve which follows the abscissas for the first forty-five minutes, and then, at about 1350°, rises sharply and gradually assumes a steady rate of expansion. Such a curve shows more obviously the point at which reaction begins and the rate at which it proceeds, but in view of the somewhat arbitrary nature of the correction and the great deal of extra work required, it is doubtful whether it is in general worth while making the additional experiments. For most purposes the uncorrected curves yield all the information required.

A study of the results given in Table V shows that the porosity of the test pieces increased during firing. The test piece fired at 1510° showed an increase of 14.5%. Hence, as with silica, the expansions measured are much greater than those expected from the theoretical calculations on bodies having zero porosities before and after firing. The decrease in density of both the magnesia and alumina when heated with 2% B_2O_3 introduces a further complication into the calculation of the amount of spinel formed. The results given in Table V are calculated on the assumption

FIG. 6.—(1) Spinel mix unfired, (2) spinel, (3) spinel mix fired at 1450°, (4) spinel mix fired at 1500°C.

that a mixture of spinel-forming oxides has a density of 3.83, and spinel itself, a density of 3.58. Since, however, the constituent unreacted oxides will be reduced in density by heating with boric acid the values calculated for the percentage of spinel formed are presumably too high.

X-ray photographs were made of the raw materials and the fired test pieces. Figure 6 shows the photographs obtained for the test pieces heated with 2% B_2O_3 to 1510°C and 1450°C, as compared with a photograph of spinel and another of the unfired test piece. It is clear that the main constituent in the fired test pieces is spinel, but that with both the 1510° and 1450° sample some residual alumina is present. The ragged lines due to the coarse fused alumina crystals (*cf.* the unfired mixture) are readily picked out. The spinel crystals are obviously small since the lines obtained are very smooth.

Test piece No. 15 (Table V) shows the result of replacing the electrically fused magnesia by dead-burned Austrian magnesite of the same grain size. No boric acid was added, and the result should therefore be compared with test piece No. 14. Almost twice as much spinel was formed, suggesting that the 7% Fe_2O_3 present in the crystals of magnesia had increased the reactivity, presumably by loosening up the lattice.

V. The Importance of Grain Size

All of the above tests on spinel were carried out with the grading known as "grade X" and given in Table II, column (2). Two further tests were made using materials of one grain size only, *viz.*, 0.15 or 0.06 millimeter + 2% B_2O_3. The initial porosity of such bodies is naturally very high, about 44%, but the number of magnesia-alumina contacts is also high because of the small grain size. The firing curves obtained (Fig. 7) were most interesting. The 0.06-millimeter material behaved quite normally until the temperature reached about 1250°. Then rapid expansion set in, the dial pointer making fourteen complete revolutions in ten minutes. At the end of this period the expansion ceased equally suddenly and rapid shrinkage set in. There would appear to be only one interpretation of this result, *viz.*, that complete reaction had taken place in approximately ten

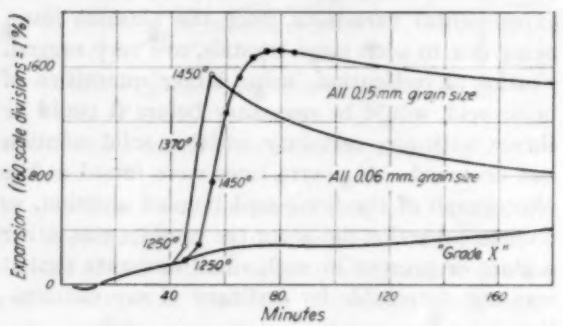

FIG. 7.—Spinels; influence of grain size on reaction speed at 1450°C.

minutes. The maximum temperature for the test was 1450°, but the expansion was complete before this temperature was attained. The final vertical expansion, after the usual two-hour run, was 5.4% and the horizontal expansion 10.6%. The density fell to 3.52, and the porosity increased to 53.5%. The low value of the density as compared with that quoted from the literature may be due to voids in the freshly formed crystals or possibly to the boric acid. X-ray examination of the product showed that the assumption of complete reaction was correct. No sign of alumina or

magnesia could be found. Certain of the main lines showed a streaky appearance suggesting that the crystals had grown to a considerable size during the shrinkage period at 1450°. The result obtained with the 0.15-millimeter material was essentially similar except that both reaction (and subsequent shrinkage) proceeded more slowly. A study of the reaction curves suggests that the rate of reaction was approximately half that obtained with the 0.06-millimeter material. The results obtained with these fine grain materials as compared with those obtained with materials having a "grade X" type grading show the enormous influence of grain size in determining reaction rates. Brick with porosities of the order of 55% would not be suitable for commercial work, except perhaps high-temperature insulation, but for the study of reaction rates the use of materials of one grain size has obvious advantages.

In the discussion of the literature, reference was made to "reactions in the solid state." The results given in this paper may not appear to have any relation to these references, since it is doubtful whether any of the tests described took place in the absence of a liquid phase. Even the test using electrically fused magnesia and alumina, without boric acid, may not have been a solid state reaction since a melt may have been formed between the magnesia, alumina, and the various impurities present. Electrical conductivity measurements would be necessary before anything definite could be stated. (The authors hope to be able to make such measurements.) In the meanwhile the results obtained with expansion measurements at constant temperature serve to show the possibility of following reactions at high temperatures and of yielding information applicable to the study of the reactions which occur in the firing and use of refractory materials.

VI. Conclusions

(1) The continuous measurement of firing expansion yields considerable information as to the rate of reaction between magnesia and alumina and the rate of inversion of quartz to cristobalite.

(2) The sensitivity of the method is such that a movement of one division on the expansion recorder corresponds to the formation of less than 0.1% of spinel.

(3) The method shows the possibility of detecting the temperature at which reaction begins, and of making approximate comparisons of reaction rates at high temperatures.

(4) The rate of reaction between magnesia and alumina and the rate of inversion of quartz to cristobalite were found to be greatly influenced by the temperature and by small additions of fluxing materials.

(5) The rate of formation of spinel was found to increase greatly with decreasing grain size.

(6) Both quartzite- and spinel-forming mixtures tend to increase in porosity during firing if high initial ramming pressures are used. The linear and bulk expansions are thus considerably greater than would be expected for bodies having zero porosity before and after firing.

Acknowledgment In conclusion the authors desire to express their thanks to The Commonwealth Fund of New York, to the University of Illinois for enabling them to carry out this work, and to G. L. Clark and R. R. Sterrett for help with the X-ray investigations.

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A STUDY OF SOME FRIT COMPOSITIONS*

By C. W. Parmelee and K. C. Lyon

ABSTRACT

The results of a study of seventy-five frits containing Na_2O, CaO, B_2O_3, Al_2O_3, and SiO_2 and properties of melting, flowing, corrosion, solubility, and p_H are reported.

I. Introduction

For various well-known reasons, it is necessary or convenient to add certain constituents to glaze compositions as glasses. These glasses, termed frits, are prepared by melting in saggers or in smelters of the rotary or drip type. For satisfactory smelting, the molten glasses must have a certain degree of fluidity and they should have little effect upon the refractory lining of the melting furnace. In addition to these desired properties in the melted state, there are others required of the frit such as low solubility, homogeneity, and friability.

It is the purpose of this paper to present the effect of frit composition on certain of these properties.

II. Review

The following contributions on this subject are found in the literature.

Rules for the compounding of frits were presented by the Committee on Equivalent Weights of the American Ceramic Society[1] in 1900 and Andrews[2] repeated and made some additions to them. Similar rules are given in the Ceramic Products Cyclopedia.[3]

Rules of a quite different sort were given by Purdy and Fox[4] and those given by Kerl[5] are dissimilar to any cited above.

Purdy and Fox[4] prepared eight frits of compositions included within the following limits:

0.194 Na_2O 0.191 K_2O 0.615 CaO	0.0–1.479 B_2O_3 0.077 and 0.615 Al_2O_3	0.615–6.40 SiO_2

These were reported suitable for preparation in drip-type laboratory smelter furnaces. The melting temperatures were not included in the published article. Solubility was judged by the appearance of the frit after quenching in water. Two frits containing no B_2O_3 were reported as being too soluble. No intra-comparison can be made because the present investigation of solubility did not include frits of this type of composition.

Blumenthal[6] studied the solubility of commercial boric acid frits of unknown composition by agitating sized samples of frit in water for a day.

Sortwell[7] made frits of feldspar, borax, and whiting having quite a range of composition in the triaxial field studied. The solubilities of these were found to be generally lower than those given by Blumenthal. Since the same method of solubility determination was used by both investigators it is supposed that their results are comparable.

Simpson[8] made solubility determinations on some eutectic mixtures prepared in studying enamel compositions.

It is impossible to compare directly the results of these investigators either among themselves or with the results shown from the present work because of the different methods of solubility determination used.

The results of cone fusion tests made on frits by Sortwell seem to indicate that a decrease of silica content must accompany increasing alumina content to maintain satisfactory fusibility.

Computations based on the published compositions of glaze frits taken from ceramic texts and journals show the general limits of

0.08–0.96 Na_2O 0.00–0.43 K_2O 0.18–0.90 CaO 0.00–0.01 MgO* 0.00–0.17 BaO 0.00–0.78 PbO	0.00–1.50 B_2O_3 0.00–0.64 Al_2O_3	0.08–6.40 SiO_2 0.00–0.41 SnO_2

* Impurity

* Presented at the Annual Meeting, American Ceramic Society, Cincinnati, Ohio, February, 1934 (White Wares Division). Received December 14, 1933.

This paper has been prepared from a thesis written by the junior author to satisfy in part the requirements for the degree of M.S. at the University of Illinois and is published with the permission of the Dean of the Graduate School.

[1] *Trans. Amer. Ceram. Soc.*, **2**, 196 (1900).

[2] A. I. Andrews, Ceramic Calculations, p. 80. John Wiley and Sons, New York, 1928.

[3] Ceramic Products Cyclopedia, p. 497. 5th ed., Industrial Publications, Inc., Chicago, 1930.

[4] R. C. Purdy and H. B. Fox, "Fritted Glazes," *Trans. Amer. Ceram. Soc.*, **9**, 95 (1907).

[5] Bruno Kerl, Handbuch der gesammten thonwaarenindustrie, p. 1149. Ed. 3. Cramer and Hecht. F. Vieweg and Son, Braunschweig, 1907.

[6] G. Blumenthal, Jr., "The Solubility of Boric Acid Frits," *Jour. Amer. Ceram. Soc.*, **3** [2], 152 (1920).

[7] H. H. Sortwell, "The Solubility and Fusibility of Some Feldspar Frits," *ibid.*, **4** [6], 446 (1921).

[8] H. E. Simpson, "The Development of an Enamel on a Eutectic Basis," *ibid.*, **13** [1], 62 (1930).

III. Experimental

Frits must have certain properties (1) so that they may be economically prepared and (2) so that they may successfully serve their purpose. The frit should be readily fusible, should have the necessary degree of fluidity at as low a temperature as possible, should not corrode the containing vessel markedly, should contain all of the soluble raw materials and no more of the insoluble than necessary, should be easily quenched and ground, should have the proper composition to fit in the glaze formula, and should have the necessary degree of insolubility.

Studies on glasses[9] and glazes have fairly well indicated what the expected effect of different constituent oxides on the properties may be. There is no need to review this material here.

In this study it has been necessary to set up certain arbitrary limits for melting temperature and characteristic viscosity. A temperature of 1100°C was chosen for the preparation of all mixtures. A melted frit which would flow through an opening of 0.5 centimeter diameter in a laboratory drip-frit pot of 3 kilograms (melted) capacity at a minimum rate of one drop per second at 1100°C was considered sufficiently fluid.

No attempt has been made to set a limit for solubility. The study of the effect of frit solubility upon glaze suspension and the glaze composition when applied to the ware is beyond the scope of the present work. According to Blumenthal,[6] a frit having solubility as high as 8% is not too soluble for use. The authors also have a communication stating that a frit having a solubility of 26% (determined on unsized grains in boiling water) is being used commercially. As both of these methods for solubility determination would yield higher results than the one used in this investigation, these limits are of little value for the present work.

The compositions of the frits used (calculated from batch compositions) are given in terms of their component oxides. These may be found presented graphically in Fig. 1. The general limits of composition were as follows:

0.3–0.7 Na_2O	0.0–1.5 B_2O_3	0.5–3.5 SiO_2
0.7–0.3 CaO	0.0–0.3 Al_2O_3	

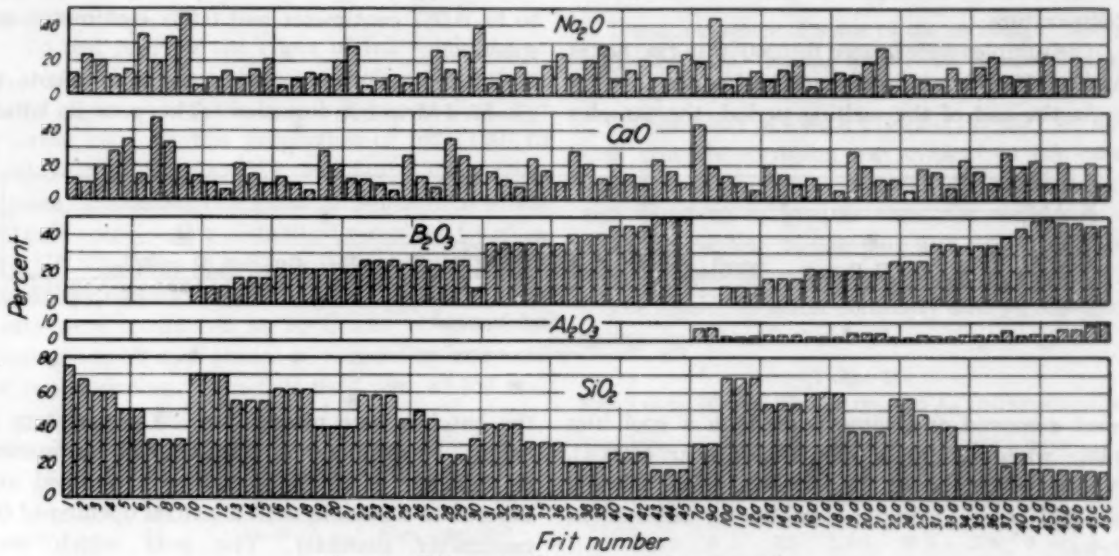

FIG. 1.—Frit compositions (molecular per cent).

The frit batches were prepared as follows:

Material	Composition Assumed
Soda ash	Na_2CO_3
Whiting	$CaCO_3$
Borax	$Na_2B_4O_7 \cdot nH_2O$*
Boric acid	H_3BO_3
China clay (see analysis, p. 62)	$Al_2O_3 \cdot 2SiO_2 \cdot 2H_2O$
Aluminum hydroxide	$Al(OH)_3$
Quartz flint	SiO_2

* n determined by loss of weight during fusion.

[9] (*a*) F. W. Hodkin and A. D. Cousen, Textbook of Glass Technology, Van Nostrand Co., New York, 1925. (*b*) W. E. S. Turner and F. Winks, "The Influence of Boric Oxide on the Properties of . . . . Glasses," *Jour. Soc. Glass Tech.*, **9**, 389 (1926). (*c*) E. Firth, F. W. Hodkin, D. Turner, and W. E. S. Turner, "The Corrosion of Fire Clay by Alkali-Lead Oxide Glasses," *ibid.*, **7**, 218 (1924).

Analysis H & G A-1 China Clay

	%
SiO_2	46.8
Al_2O_3	38.1
Fe_2O_3	0.3
CaO	0.1
MgO	0.4
Alkali as Na_2O	2.6
Ignition loss	12.9

1.00 Al_2O_3 2.08 SiO_2 1.92 H_2O

Raw batches of 300 grams weight were mixed by passing through a 20-mesh sieve three times with intermediate rolling on paper. For melting, six samples were placed in crucibles in a sagger in a gas-fired furnace and the sagger was covered. The junction of a chromel alumel thermocouple was imbedded in flint in a seventh crucible placed in the center of the sagger for the determination of temperature.

The samples were heated to 1000°C in two hours and to 1100°C in an additional half hour.

At the end of the melting period, the samples were removed and some poured on a cool iron plate while still at a temperature near 1100°C. Those which could be poured were allowed to cool before being broken up for subsequent tests.

The decrease of thickness of crucible wall by corrosion was observed by sectioning the crucible.

The frits which could be poured from the melting crucibles were crushed in a steel mortar to pass a 20-mesh sieve. The portion which was retained on a 30-mesh sieve was passed over an electromagnet to remove iron and washed with absolute alcohol to remove dust. Samples of about eight grams in weight which had been dried at 120°C and cooled in a desiccator were weighed to the nearest milligram and placed in paraffin-coated one-pint glass jars, neutral distilled water fifty times the weight of the sample being added. The jars were sealed for forty-eight hours during which they received periodic vigorous shakings. At the end of the period the p_H value of the water was determined colorimetrically and the undissolved sample was filtered, ignited, and weighed to obtain the per cent loss of weight by solution.

Measurement of cross-sections of grains from eleven samples of sized frit chosen at random showed a mean of 0.087$_6$ centimeter. Ninety grains, lying at random, were measured by two ninety-degree traverses of a micrometer microscope. The distribution of measurements was as follows:

Centimeter	Per Cent
Under 0.04	0
0.04–0.06	7
0.06–0.08	40
0.08–0.10	29
0.10–0.12	16
Over 0.12	8

The average sizes of screen openings were found to be 0.087 centimeter and 0.054 centimeter, respectively.

Fluidity tests on raw batches were made in gas-fired drip-frit furnaces. The pots in which the batches were placed were 25 centimeters in height, 1 centimeter in thickness, 11 centimeters in diameter at the top, and were rounded and tapered to a bottom with a central opening of 0.5 centimeter diameter. The pots which were placed in individual gas-fired furnaces were heated to a dull red heat at which time the raw batches were introduced. The heating was then continued until the surface of the molten frit was found by optical means to be 1100°C. At this temperature and with the pots about half filled, the rate of dropping from the lower orifice was observed.

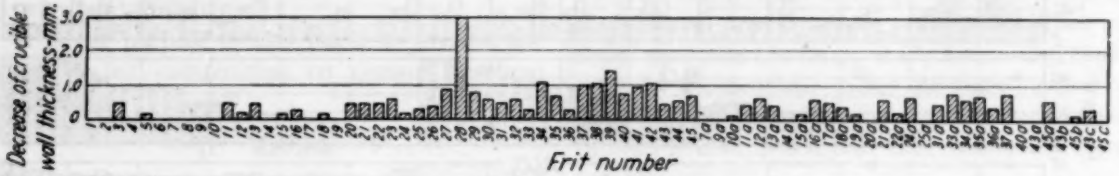

FIG. 2.—Crucible corrosion.

Fluidity tests on a smaller scale were carried out in glazed porcelain crucibles of 15 cubic centimeters capacity drilled to give a 0.4 centimeter diameter opening through the bottoms. The vessels, tightly packed with raw batch, were preheated in an electrical resistance furnace at 350°C for five minutes and then were quickly transferred to another electrical resistance furnace at 1060°C. The sample was supported in the center of the furnace chamber of 3.5 centimeters

diameter and 34 centimeters length. The chamber, placed vertically, was open at the lower end and was closed at the upper end except for a small peephole.

The flow characteristic was determined by noting the total time necessary for drops to fall after the crucible had been placed in the furnace at 1060°C. Only the compositions which had previously been observed as comparatively viscous at the time of pouring were tested for flow characteristic.

In making the tests with the small crucibles it was noted that the molten glass tended to spread from the orifice over the bottom. The use of a containing vessel with a short dropping tube to give uniform drop formation might have been more satisfactory.

To test roughly the effect of frit solubility or p_H value on the suspension of a glaze, four simulated glazes were made from frit, quartz flint, and Florida clay, in the proportion of frit (120- to 150-mesh) 50%, clay 5%, and flint 45%. Each "glaze" contained 14.6 grams of solids with which 50 cubic centimeters of distilled water (no Ca, Mg, Fe, Cl, SO_4) were mixed in a 100-cubic centimeter capacity cylinder by vigorous shaking. The tests were conducted at 26°C and observations were made on appearance of suspension and ease of re-suspending. The frits used were as follows:

Glaze No.	Frit No.	Character of Frit
12	12	Low p_H; low solubility
26	26	Medium p_H; medium solubility
30	30	High p_H; medium solubility
45	45	Medium p_H; high solubility

Some observations were made on the coloring of frit glasses by materials from the crucibles.

Undissolved material in some of the frits was identified by petrographic methods.

Properties of additional fritted glaze suspensions prepared at the University of Illinois were observed. The frit compositions covered variations in Na_2O, K_2O, CaO, PbO, B_2O_3, Al_2O_3, and SiO_2.

IV. Results

Frit compositions, too viscous to pour after melting, are listed by number in Table I and the appearances of the residues are described. Considering the compositions, it seems apparent that B_2O_3 and Na_2O are effective in promoting fluidity.

TABLE I

FRITS REMAINING IN MELTING CRUCIBLES

Frit No.	Appearance of the Material Left in Crucible
1	Some evidence of fusion; very viscous
2	Sintered
3	Some evidence of fusion; less viscous than No. 1
4	Sintered; less bond than No. 2
5	Calcined; very little bond
6	Evidence of fusion; about as viscous as No. 1
7	Very slightly sintered
8	Sintered; more than No. 7, less than No. 4
9	Melted to solid opaque glass in bottom of crucible
10	Melted down; glass full of large bubbles
11	Better fusion than No. 10; large bubbles
16	Melted down; white vitreous mass full of small bubbles
22	Nearly the same as No. 16
7a	Sintered
9a	Sintered more than No. 7a; more than No. 2
10a	Fused; glass full of large bubbles
11a	Melted down; smaller bubbles than No. 10a
16a	About the same as No. 16
22a	About the same as No. 16a

The appearance of some of the melting crucibles indicated that "boiling over" had occurred when the $Na_2O:B_2O_3$ ratio was less than 0.45.

On the basis of visual evidence, it may be said that crucible corrosion was evident in the cases where the sum of the molecules of Na_2O and CaO was equal to or greater than the molecules of SiO_2. According to Salmang and Schick,[10] Na_2O is more active than CaO.

The results of water-solubility and p_H determinations are given in Table II.

TABLE II

RESULTS OF WATER-SOLUBILITY AND p_H DETERMINATIONS

Frit No.	Solubility (%)	p_H	Frit No.	Solubility (%)	p_H	Frit No.	Solubility (%)	p_H
12	0.05	7.7	30	1.27	10.8	17a	0.16	8.4
13	0.38	9.0	31	0.74	9.0	18a	0.17	8.4
14	0.19	8.1	32	1.11	8.9	19a	0.43	9.6
15	0.50	9.1	33	1.06	8.9	20a	0.56	9.4
17	0.51	8.7	34	1.16	9.1	21a	0.84	9.5
18	0.29	8.7	35	1.78	9.6	24a	0.29	8.4
19	0.90	9.2	36	2.21	9.2	31a	1.24	9.0
20	1.42	9.5	37	1.59	9.1	33a	0.96	8.9
21	1.73	9.4	38	2.62	9.2	34a	0.91	9.4
23	0.78	8.9	39	3.55	9.2	35a	1.04	9.2
24	0.54	8.6	40	1.68	9.0	36a	1.69	9.2
	0.56		41	1.81	9.1	37a	1.18	9.6
25	0.86	9.1	42	2.80	9.1	40a	1.55	9.1
26	0.84	9.7	43	2.30	8.9	43a	0.08	9.0
27	1.23	9.2	44	3.20	9.0	45a	2.70	9.1
28	1.10	10.1	45	5.51	9.1	43b	0.19	8.9
29	1.72	10.3	12a	0.08	7.7	45b	2.71	9.1
	1.71	10.3	13a	0.29	8.7	43c	0.99	8.8
30	1.23		14a	0.15	8.5	45c	1.95	9.0
	1.24	11.0	15a	0.12	8.4			

NOTE: Check values are recorded in a few cases. It is thought that these results are fairly reliable. Those from Nos. 13, 17, 23, and 25 seem to be in error but these were some of the glasses showing the presence of undissolved material.

[10] H. Salmang and F. Schick, "IV, The Corrosive Power and Constitution of Iron Works Slags," *Stahl u. Eisen*, **50**, 1814; *Trans. Ceram. Soc.* [Eng.], **30**, 12 (1931).

The glasses containing Al_2O_3 seemed to show inconsistencies in solubility, possibly due to incomplete homogenizing in the short melting period.

If the results from the solubility tests in the system Na_2O–CaO–B_2O_3–SiO_2 are examined, a certain degree of coördination between the ratio

$$\frac{\text{Mol } Na_2O + \text{mol } B_2O_3}{\text{Mol CaO} + \text{mol } SiO_2}$$

and the percentage solubility is found as shown in Fig. 3. In this particular case, the result reduces to

$$\text{Solubility (\%)} = -0.23 + 1.703\,\frac{(\text{mol } Na_2O + \text{mol } B_2O_3)}{(\text{mol CaO} + \text{mol } SiO_2)}$$

This result does not include the point on the extreme right of Fig. 3. This point, representing frit No. 45, indicates the trend of the solubility

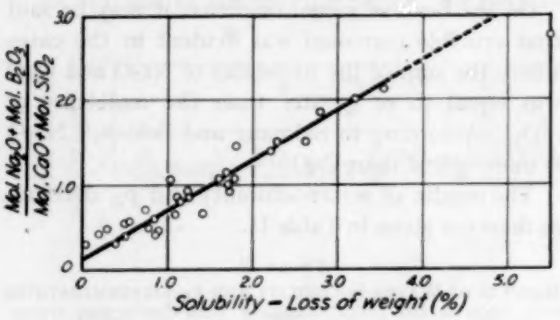

FIG. 3. Solubility and composition, Na_2O–CaO–B_2O_3–SiO_2.

but its position should be verified by further work. The above equation requires that there be a linear relation between solubility and composition as shown. That this is not strictly true is indicated by the work of Keppeler and Ippach.[11]

It is seen from the results that small additions of alumina markedly decreased frit solubilities and further additions resulted in further decreases, but not proportionately. No simple relation for the phenomenon could be found nor did the results of the work of others yield themselves to ready adaptation. Dimbleby and Turner[12] have shown that alumina was about three times as effective as lime in reducing solubility of simple glasses.

[11] G. Keppeler, and H. Ippach, "The Stability of Glasses in the Soda–Lime–Silica System," *Sprechsaal*, **60**, 239, 261, 281, 297 (1927).

[12] V. Dimbleby and W. E. S. Turner, "The Relationship between Chemical Composition and the Resistance of Glasses to the Action of Chemical Reagents, I," *Jour. Soc. Glass Tech.*, **10**, 304 (1926).

The relation between p_H and time of treatment given in Fig. 4 shows that the maximum value had been obtained, at least for the particular frit studied.

While no connection between p_H and solubility was apparent, it may be seen that decrease of SiO_2 or B_2O_3 with Na_2O and CaO constant resulted in higher p_H values being obtained.

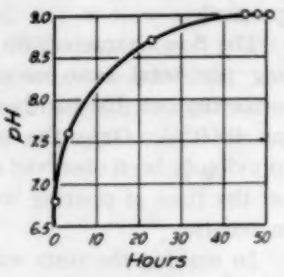

FIG. 4.—Time-p_H relation water over frit No 13.

The results of the tests of flow characteristics are given in Table III and the data from the small-scale tests are

TABLE III

RESULTS OF FLOW TESTS

Laboratory Drip-Frit Pots

Frit No.	Temp. °C	Rate
12	1000	No flow
	1185	About 30 drops per minute
13	1100	Slightly greater than 1 drop per second
17	1000	No flow
	1100	1 drop per second
18	1100	1½ drop per second
11a	1100	No flow
	1200	12 drops per minute
	1250	30 drops per minute

SMALL SCALE TESTS

Frit No.	Total Time Required for Drop Formation (minutes) (1)	(2)	(3)	(4)
17	10.42	11.58	13.02	14.47
17	10.78	12.05	13.47	14.56
18	8.75	9.75	10.81	11.97
23	12.75	14.83	16.58	
45	2.67	2.72	2.77	2.82
17a	16.92	20.05		
18a	9.08	10.20	11.28	
45b	3.77	3.92	4.23	

plotted in Fig. 5. Since No. 17 had the fluidity defined as the limiting value, two determinations made with this composition on a smaller scale served to calibrate the small-scale tests and to show the reliability of the method. Inspection of the data revealed that of the frits which could be poured from melting, Nos. 12, 23, and 17a had too little fluidity as the limit was defined. From the known effect of alumina, Nos. 12a and 23a would be suspected of being too

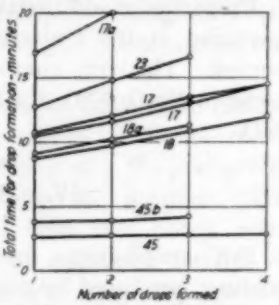

FIG. 5.—Results of flow tests.

viscous. The effect of the alumina was shown in comparison of results from 17, 18, and 45 with 17a, 18a, and 45b.*

In the four-component system, Na_2O–CaO–B_2O_3–SiO_2, the last member was the most effective in decreasing fluidity. The effect of B_2O_3 in increasing fluidity was not so marked beyond the first increment. Additions of soda, which always replaced lime in compositions of the type studied, seemed to have a marked effect in increasing fluidity.

The limiting conditions, within the scope of compositions studied, for satisfactory fluidity seem to have been as follows:

SiO_2 less than 3.0 equivalents
B_2O_3 greater than 0.5 equivalent
Na_2O greater than 0.3 equivalent
Al_2O_3 less than 0.1 equivalent

The method of studying fluidity was influenced by surface-tension effects. Generally, constituent oxides decreasing fluidity also increase surface tension of glasses.[13]

The results of suspension tests given in Table IV show that frit solubility did play a rôle in glaze suspension. Glaze 12 was harder to re-suspend than one containing a frit of higher solubility. It would seem that frit No. 45 was too soluble, at least for use in glazes likely to be subjected to periods of standing without agitation. The results indicate that a frit of high p_H value might be somewhat harder to re-suspend than one less basic. The settling of these glazes was very rapid, probably because of large particles and excess water.

TABLE IV

RESULTS OF SUSPENSION TESTS

Glaze No.	Description
	First Day
12	Supernatant liquid the most murky of the four studied; eleven complete reversals of the cylinder necessary before glaze re-suspended.
26	Supernatant liquid murky; three reversals of the cylinder necessary to re-suspension.
30	Supernatant liquid clearer than that of No. 26; two reversals necessary for re-suspension.
45	Supernatant liquid clear; five reversals required for re-suspension.
	Fifth Day
12	Seventeen reversals necessary for re-suspension.
26	Three reversals necessary for re-suspension.
30	Five reversals necessary for re-suspension.
45	Re-suspension impossible, even with prolonged vigorous shaking.

The rate of settling seemed to decrease in the order 45, 30, 26, and 12. This quality was difficult to judge because of the turbidity of some of the supernatant liquids.

Regarding suspensions, Harrison's[14] study of enamel slips indicate (1) that considerable change in viscosity of an enamel slip might take place without change in the p_H value of the suspending liquor and (2) an enamel made from a frit having high borax content showed less change in consistency in aging than one made from a frit of high silica content. This conclusion suggests that the consistency of a slip containing a frit of low solubility changes more in aging than one more soluble. Andrews[15] reports that the "setting up" of an acid-proof enamel slip is difficult, presumably because of use of frit of low solubility.

The appearance of glaze No. 12 after settling indicated that its clay was deflocculated. Addition of borax solution to Harrison's[14] suspensions caused flocculation of the finer particles. Cook[16] has found Na_2O and B_2O_3 to be dissolved in water from frits containing them. The flocculation in the case of No. 45 (see Table IV) may have been due to the presence of materials dissolved from the frit.

Frits Nos. 22, 23, and 31 were opal glasses. They had a high silica content and fairly high B_2O_3 content. Frits Nos. 25, 26, and 27 were yellow and Nos. 28, 29, and 30 were green. The difference in color could not be attributed to atmospheric conditions because these were all melted in the same sagger. Inspection of the compositions revealed that the last group was more acid in its character than the one immediately preceding it.

Undissolved material found in frits Nos. 12, 13, 17, 23, 25, 31, 40, 13a, 14a, 17a, 25a, 31a, 40a, and 43a was determined as quartz by optical sign and index of refraction. The material, from a microscopic standpoint, was in comparatively large grains with rounded edges.

Since uncombined silica is sometimes found with molten glass in glass tanks, it is not surprising that it should have occurred in the making of

* The suffixed letters "a" and "b" indicate that the respective proportions of soda, lime, boric oxide, and silica were the same as in the compositions without suffix, but that amounts of alumina were also included.

[13] A. Lecrenier, "Measurement of the Surface Tension of Glass," *Bull. Soc. Chim. Belg.*, **33**, 119 (1924); *ibid.*, **34**, 27 (1925).

[14] W. N. Harrison, "Vitreous Enamel Slips and Their Control," *Jour. Amer. Ceram. Soc.*, **10** [12], 970 (1927).

[15] A. I. Andrews, Communicated.

[16] H. L. Cook, "Note on the Solubility of Enamel Frit in Mill Water," *Jour. Amer. Ceram. Soc.*, **10** [5], 339 (1927).

these frits. Lime, which seemed to be more active in crucible attack when silica content was low, appeared to be less effective than soda in absorbing larger amounts of silica. Disregarding any B_2O_3 or Al_2O_3 present, one may treat the occurrence of the undissolved silica in the light of the Na_2O–CaO–SiO_2 system of Morey and Bowen.[17]

Examination of Morey and Bowen's ternary diagram revealed that some form of SiO_2 may be expected as a crystalline phase with melts made from Na_2O, CaO, and SiO_2 when the silica content is high and the temperature near 1100°C.

Generally speaking, the fritted glazes prepared by the University students were easier to keep in suspension when the frits contained some B_2O_3. Those in which the frits contained only Na_2O, CaO, PbO, and SiO_2 frequently settled out in hard masses which were very difficult to re-suspend. A small quantity of borax added to the liquor of one of the latter type seemed to improve its suspension property.

While it seemed that the solubility of these glazes aided in their suspension, some account must be taken of the fact that the lead frits had a higher density than the boric oxide frits.

V. Conclusions

The results of this investigation seemed to justify the following conclusions which apply to frits composed of Na_2O, CaO, B_2O_3, Al_2O_3, and SiO_2.

(1) For easy fusibility and satisfactory fluidity, some B_2O_3 must be included in the compositions. The SiO_2 content should not exceed 3.0 equivalents, the Na_2O and CaO may vary from 0.3 to 0.7 equivalent, alumina may be present at least up to 0.1 equivalent, and the B_2O_3 content need not be greater than 0.5 equivalent.

(2) To prevent excessive corrosion of the smelter lining, the SiO_2 content should be greater than 1.0 equivalent.

(3) (*a*) The solubility of the frit glass in water is roughly proportional to the molecular ratio

$$\frac{Na_2O + B_2O_3}{CaO + 6SiO_2}.$$

Small additions of alumina (in the order of 0.1 equivalent) may be expected to reduce the solubility by about one-half. (*b*) A frit of low solubility can be produced without the introduction of Al_2O_3.

These conclusions may be compared with the following summary from the Report of the Committee on Equivalent Weights of the American Ceramic Society.[1]

(1) For easy fusibility the number of acid molecules should not be less than the number of basic nor more than three times that number. (Compare with (1) and (2) above.)

(2) Alkali silicates are soluble. To produce insoluble frits some base forming an insoluble silicate should be used with the alkali. Two other bases besides alkali should be used if possible, one of these being alumina if the formula permits. The acid element should always contain silica. The proportion of boric acid should not be more than one-half the silica. (Compare with (3) above.)

Appendix Certain manufacturers have kindly forwarded the compositions of frits which they prepare in smelters. In the cases where it has been necessary to calculate from batch, the typical composition of the particular brand of feldspar and the theoretical compositions of all other components have been used.

Commercial Frit Compositions

(Molecular Equivalents)

No.	Na_2O	K_2O	CaO	PbO	B_2O_3	Al_2O_3	SiO_2
1	0.05	0.09	0.76	0.10	0.67	0.09	1.80
2	.239	.225	.536		.478	.226	2.48
3	.081	.050	.767	.107	.710	.095	1.93
4	.053	.065	.493	.390	.737	.099	2.005
5	.065	.043	.810	.083	1.117	.076	1.599
6	.061	.089	.573	.278	0.372	.144	1.931
7	.072	.037	.785	.107	.677	.081	2.185
8	.279	.023	.699		.548	.242	2.372
9	.279	.010	.382	.329	2.31	.295	7.53
10	.081	.049	.763	.109	0.710	.095	1.713
11	.284	.017	.699		.549	.298	2.54
12	.27	.04	.69		.54	.27	2.53
13	.360	.088	.552		4.691	.160	6.265
				MgO			
14	.365	.067	.477	.091	1.000	.149	3.000
15	.278	.023	.699		0.547	.274	2.56
16	.267	.027	.680	.010	0.545	.266	2.576
				PbO			
17	.194	.033	.194	.580	0.230	.065	2.44

[17] G. W. Morey and N. L. Bowen, "The Ternary System: Sodium Metasilicate–Calcium Metasilicate–Silica," *Jour. Soc. Glass Tech.*, **9**, 226 (1925).

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THE MICROSTRUCTURE OF SOME RAW LEAD MAT GLAZES*

By C. W. Parmelee and William Horak

ABSTRACT

This is a report on the microstructure of mats found in the following composition range:

$$\left.\begin{matrix}0.4\text{–}0.6\ PbO\\0.2\text{–}0.3\ CaO\\0.0\text{–}0.3\ BaO\\0.0\text{–}0.3\ ZnO\end{matrix}\right\}\ 0.1\ \text{to}\ 0.35\ Al_2O_3\quad 0.7\ \text{to}\ 1.8\ SiO_2$$

These were fired at cones 03, 2, 4, and 6. The compounds present recognized as crystals were anorthite, celsian (probably), tridymite, and wollastonite. Willemite was not observed. The good mats were due to crystal separations. A high alumina content was not essential. Anorthite was the principal crystalline form present in mat glazes containing lime.

I. Introduction

A mat glaze is one without gloss but it has a satiny texture and is smooth to the touch without any degree of harshness. The ideal mat texture has been compared to that of a fine undressed kid glove.[1]

Mat glazes are generally divided into three classes[2] as follows: (1) mats due to immaturity, (2) mats due to crystallization and called "true mats," and (3) mats due to gas vesicles or surface structure.

Mats of the raw lead type have generally been considered to be of the first two classes, and a number of them have proved to be crystalline, but none of the published results seems to have covered a general field nor has there been any attempt to identify the crystals contributing to the mat texture.

The purpose of this investigation is to study the microstructure of certain mat glazes. It is not an investigation of the possible means and fields for developing mat glazes but a study of the microstructure of those whose compositions fall within the following range:

$$\left.\begin{matrix}0.4\text{–}0.6\ PbO\\0.2\text{–}0.3\ CaO\\0.0\text{–}0.3\ BaO\\0.0\text{–}0.3\ ZnO\end{matrix}\right\}\ 0.1\ \text{to}\ 0.35\ Al_2O_3\quad 0.7\ \text{to}\ 1.8\ SiO_2$$

The limits chosen were based on published and unpublished data available.

II. Literature

Binns,[3] in his early work on mat glazes, found that an increase in the alumina content tended toward the formation of a mat texture. In the discussion of his paper, others brought out the fact that in some cases increase in silica with fairly low alumina also tended toward a mat texture. Binns attributed the matness in glazes to the excess alumina remaining suspended in the glaze.

Stull[4] studied the porcelain glaze field; Sortwell[5] extended the work to higher temperatures; and Twells[6] further extended it by varying the RO oxides. Thompson[7] studied the microstructure and the crystals causing the matness in the same field covered by Stull.

Purdy[8] advanced a theory for the development of mat glazes on the basis of the existence of certain norms. The essential requirement is the presence of a glass to which an excess of "feldspars," *i.e.*, leucite, anorthite, and orthoclase, is added. Quoting Purdy, "Our theory does not say that these feldspars are being formed, although we believe such to be the case."

Potts[9] and, later, Whitford[10] did work in defense of Purdy's theory. Whitford found in his work that mats formed at the higher alumina contents, but he also found in his zinc silicate series that 0.1 equivalent Al_2O_3 gave mats. Most of his glazes in this series were bright. He concluded that matness is a function of temperature as well as composition.

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* Presented at the Annual Meeting, American Ceramic Society, Cincinnati, Ohio, February, 1934 (White Wares Division). Received December 16, 1933.

This investigation was conducted by the junior author to satisfy the thesis requirements for the degree of Bachelor of Science.

[1] C. L. Thompson, "The Microstructure of Some Porcelain Glazes," Univ. of Illinois, Eng. Expt. Station, *Bull.* No. 225.

[2] H. F. Staley, "Microscopic Examination of Twelve Mat Glazes," *Trans. Amer. Ceram. Soc.*, **14**, 691 (1912).

[3] C. F. Binns, "The Development of Mat Glazes," *Trans. Amer. Ceram. Soc.*, **5**, 50 (1903).

[4] R. T. Stull, "Influences of Variable Silica and Alumina on Porcelain Glazes of Constant RO," *ibid.*, **14**, 62 (1912).

[5] H. H. Sortwell, "High Fire Porcelain Glazes," *Jour. Amer. Ceram. Soc.*, **4**, 718 (1921).

[6] R. Twells, Jr., "The Field of Porcelain Glazes Maturing between Cones 17 and 20," *ibid.*, **5** [7], 430 (1922); "Further Studies of Porcelain Glazes Maturing at High Temperatures," *ibid.*, **6** [11], 1113 (1923).

[7] See footnote 1.

[8] R. C. Purdy, "Mat Glazes," *Trans. Amer. Ceram. Soc.*, **14**, 671 (1912).

[9] A. P. Potts, "Notes on Mat Glazes," *ibid.*, **15**, 628 (1913).

[10] W. G. Whitford, "A Study of Three Component Normative Systems in Raw Lead Glazes," *ibid.*, **19**, 312 (1917)

Pence[11] presented microscopical evidence that the matness of three types of mats, calcium, zinc, and barium, was due to crystallization. These glazes were lead glazes approaching the compositions covered in this thesis, except that his glazes all contained some K_2O. Pence did not identify any of the crystals in his mats.

Heubach[12] defended the crystallization theory and advanced further microscopical evidence. He also showed that a porcelain glaze normally firing bright could be made into a good mat by devitrifying it through slow cooling.

Worcester[13] found that introduction of alumina into a crystalline glaze changed the form of the crystals.

Staley[14] examined twelve mat glazes with a microscope and found only two of them to be crystalline. The compositions of most of these glazes were unknown.

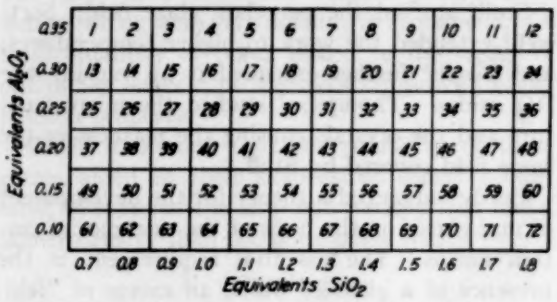

FIG. 1.—Diagram showing numbering of glazes.

III. Experimental Work

NOTE: The experimental work on this problem was divided into two parts.

Part 1 consisted in making up and firing a single series of glazes to various temperatures to determine the proper firing limits.

Part 2 consisted in making up the three most important types of mat glaze series, calcium, barium, and zinc, and firing these within the limits determined in Part 1.

Part 1. Preliminary This series of glazes, designated as series P, had the following composition:

$$\left.\begin{matrix}0.60\ PbO\\0.40\ CaO\end{matrix}\right\}\ xAl_2O_3 \quad ySiO_2$$

In this series and all others in this paper, except series S, x varied from 0.1 to 0.35 equivalent of alumina, and y from 0.7 to 1.8 equivalent of silica.

These glazes were fired to cones 03, 2, 4, and 6. The results of these firings are shown in Figs. 2 3, 4, and 5, respectively. Figure 1 shows the manner in which the glazes in the series were numbered.

As can be seen from the figures, the cone 03 and cone 2 firings gave a large number of immature glazes and it was decided to fire the remaining series only to cones 4 and 6.

When series P was fired, an arbitrary method of grading the glazes was adopted and applied to all series. The diagrams show the glazes as graded and are self-explanatory. The designation "rough brights" indicates bright glazes which were rough, having a curdled appearance, the cause for which was unknown.

Part 2 This work consisted in making up the subsequent series and firing within the limits determined in Part 1 (cones 4 and 6). The series as made up had the following compositions:

Series A

$$\left.\begin{matrix}0.6\ PbO\\0.3\ CaO\\0.1\ BaO\end{matrix}\right\}\ xAl_2O_3 \quad ySiO_2$$

Series C

$$\left.\begin{matrix}0.4\ PbO\\0.3\ CaO\\0.3\ ZnO\end{matrix}\right\}\ xAl_2O_3 \quad ySiO_2$$

Series B

$$\left.\begin{matrix}0.4\ PbO\\0.3\ BaO\\0.3\ CaO\end{matrix}\right\}\ xAl_2O_3 \quad ySiO_2$$

Series D

$$\left.\begin{matrix}0.4\ PbO\\0.2\ BaO\\0.2\ CaO\\0.2\ ZnO\end{matrix}\right\}\ xAl_2O_3 \quad ySiO_2$$

The values of x and y in all the above series are the same as given for series P.

After firing series C to cone 6, it was noticed that glaze 72 (see Figs. 1 and 12) had a semi-bright appearance indicating a tendency toward matness. A new series having the same RO as series C, but with extended SiO_2 was made up and called series S (see Figs. 14 and 15) having the following compositions:

Series S

$$\left.\begin{matrix}0.4\ PbO\\0.3\ CaO\\0.3\ ZnO\end{matrix}\right\}\ 0.1\text{ to }0.2\ Al_2O_3 \quad 1.8\text{ to }2.4\ SiO_2$$

(a) Preparation of Glazes The glazes were prepared from the usual raw materials, which were assumed to conform to the theoretical formulas.

Glazes Nos. 1, 12, 61, and 72 in each series were made up and the intermediate compositions

[11] (*a*) F. K. Pence, "A Theory for the Cause of Matness in Glazes," *Trans. Amer. Ceram. Soc.*, **14**, 682 (1912); (*b*) "Mat Glazes," *ibid.*, **15**, 413 (1913).

[12] A. R. Heubach, "Notes on the Cause of Matness in Glazes," *ibid.*, **15**, 591 (1913).

[13] W. G. Worcester, "The Function of Alumina in a Crystalline Glaze," *ibid.*, **10**, 450 (1908).

[14] See footnote 2.

were prepared from these by blending in equivalent proportions. The end-point glazes (Nos. 1, 12, 61, and 72) were made up in 2000-gram batches and milled wet for three hours.

Alumina in all cases was introduced in the form of clay. About 10% of the batch weight in all cases was raw Florida clay which was used to keep the glaze in suspension. The remaining clay was added as calcined North Carolina kaolin, to avoid cracking and peeling off of the glaze before firing due to too high a shrinkage of the raw glaze on the tile. All silica required over that supplied by the clay was added as flint. Calcium and barium were introduced as the carbonates and zinc as the calcined oxide.

(b) Application and Firing The glazes were applied to biscuit wall tile by dipping. Each glaze was applied heavy and thin, the heavy application being about 0.5 millimeter and the light application about 0.1 millimeter. The edges of all the trials were trimmed and the tile marked for identification.

The tile were set in saggers with pyrometric cones and were fired in an oil-fired test kiln to the temperatures previously stated. The rate of temperature rise was 50°C per hour up to 600°C and 35°C per hour from 600°C to within 250°C of the finishing temperature, the rate of the last 250°C being 20°C per hour. The kiln then was allowed to soak at the finishing temperature for two hours to insure uniformity. It was allowed to cool normally and the tile could be drawn two days later.

(c) Examination of Fired Glazes After firing, the various tile were sorted into their corresponding fields and graded as shown on the figures.

A number of typical mats was picked from each field and thin sections were made of the heavy dipped glazes. Since they were about 0.5 millimeter thick, while thin sections are only about 0.03 millimeter thick, there was little chance of any tile adhering to the thin section.

(d) Quenching Tests After a preliminary examination of the thin sections under a microscope, it was observed that the crystals which had developed were small and were so enveloped by glass as to make their positive identification troublesome. It was thought that by melting the raw glazes in small crucibles at about 1100°C and holding them at this temperature for a time the crystals might grow larger, but the results were not successful.

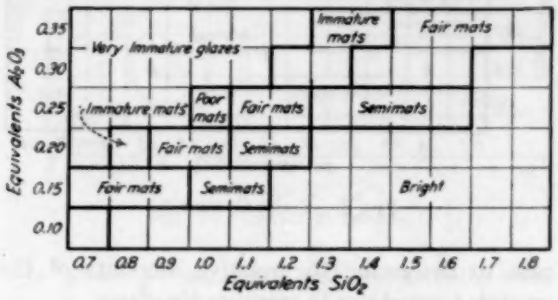

FIG. 2.—Series P, cone 03.

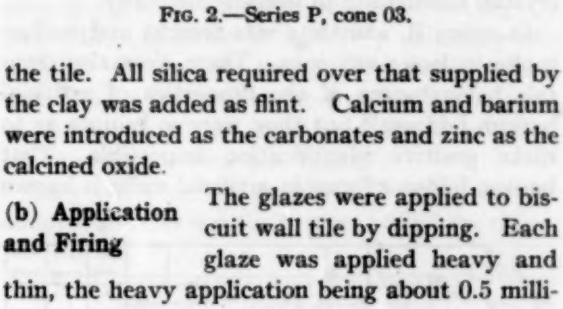

FIG. 3.—Series P, cone 2.

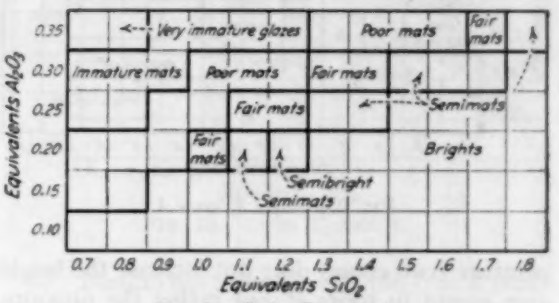

FIG. 4.—Series P, cone 4.

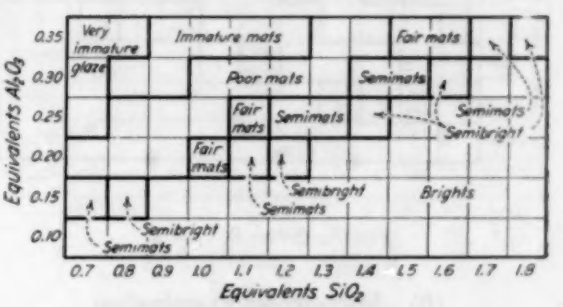

FIG. 5.—Series P, cone 6.

IV. Results

(A) Macroscopic Examination

The macroscopic appearance of the glazes after firing to cones 4 and 6 is shown in Figs. 2 to 15.

In general, in all series, the best mats formed at the higher temperatures. The increase in temperature (two cones) does not increase the bright area except in series P, but rather the opposite, mats or semimats being found at the higher temperature where brights or semibrights were formed at the lower temperature. This is probably due to the decrease in viscosity accompanying the increase in temperature, which allowed the crystals to grow more readily.

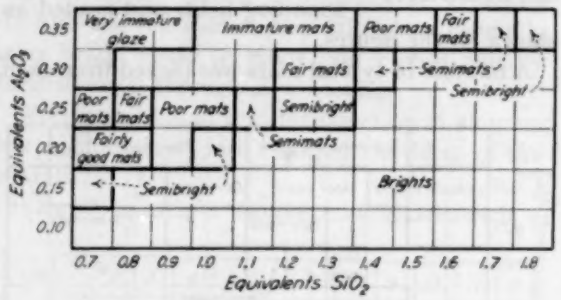

FIG. 6.—Series A, cone 4.

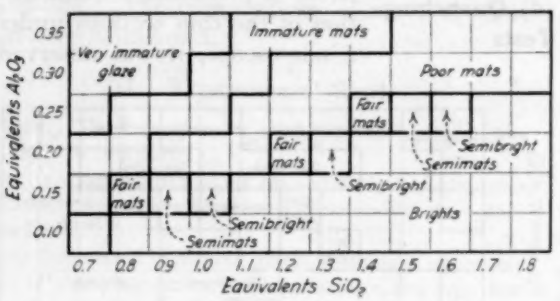

FIG. 7.—Series B, cone 4.

(B) Microscopic Examination

The glazes selected for microscopic examination showed that all the mats were crystalline; at the higher temperatures the crystals were somewhat larger. Those at lower temperatures and with higher silica content contained some undissolved quartz grains which were surrounded by glass, causing the bright spots which spoiled the good mat texture. In some instances, inversion rims of tridymite were observed.

(1) General Results by Series

The mats in series P and A consisted of crystals of anorthite and wollastonite imbedded in a glassy matrix. The optical properties of these corresponded to those usually given for the artificial products.[15] The anorthite seemed to predominate, though no attempt was made in any case to determine the relative amounts of the crystals formed nor to measure their size.

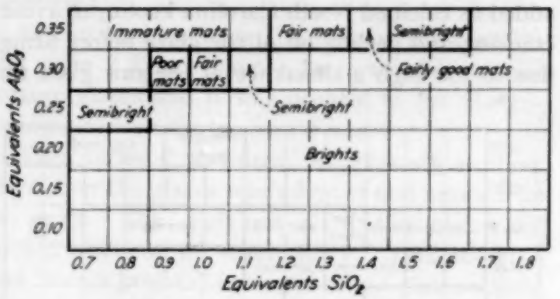

FIG. 8.—Series C, cone 4.

In series B, anorthite was present and wollastonite in lesser amounts. There were also crystals having some of the properties of artificial barium feldspar[15] but they were so minute as to make positive identification impossible. That barium feldspar forms in artificial melts is known to be a fact.[16] In nature it occurs as the rare barium feldspar, celsian. Eskola[16] found it to form in artificial melts and to be isomorphous with anorthite within certain limits. It thus seems probable that it may form in glazes containing barium, silica, and alumina as in series B,

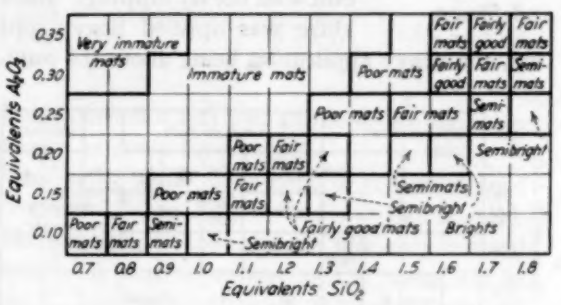

FIG. 9.—Series D, cone 4.

[15] A. N. Winchell, The Microscopic Characters of Artificial Inorganic Solid Substances or Artificial Minerals. John Wiley and Sons, New York, 1931.

[16] P. Eskola, "Silicates of Strontium and Barium," *Amer. Jour. Sci.* [5], **4**, 364–75 (1922).

and where lime is present to be isomorphous with the artificial anorthite formed.

In series C, anorthite and wollastonite were present. The crystals in this series were larger than in any of the others. Willemite, the zinc silicate, did not crystallize out, probably because the concentration of zinc in the glaze must be higher than it was in these series.

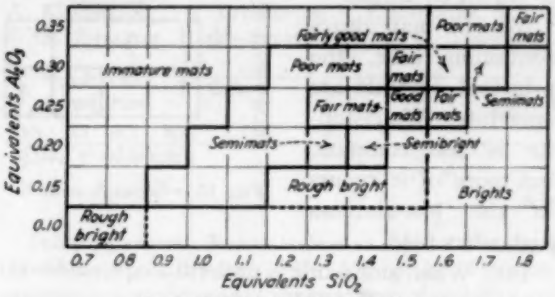

FIG. 10.—Series B, cone 6.

In series D, anorthite and wollastonite were present. The crystals were very small but slightly larger than in series B, and very uniformly distributed throughout the glassy matrix, which accounts for the large number of fairly good mats in this series. The crystals suspected of being barium feldspar were also present.

Only one glaze of the small S series was examined, and this was the best mat of all the series.

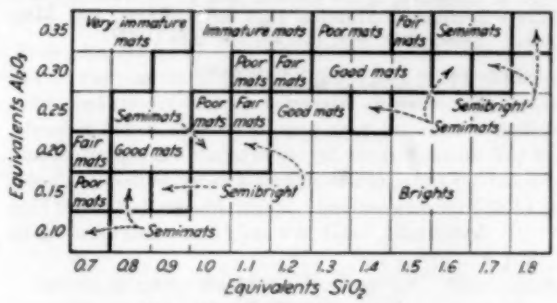

FIG. 11.—Series A, cone 6.

The crystals were radiating needles of tridymite, some quartz showing inversion to tridymite and also crystals of anorthite and wollastonite.

V. Summary

(1) The good mats within the fields of raw lead glazes studied owe their matness to crystallization.

(2) Anorthite is the chief crystalline component in all of these mat glazes.

(3) The alumina-silica ratio has the effect of regulating the viscosity of the glaze so that the crystals do not grow too large to spoil the mat texture. Increase of alumina of the glaze tends to give a large number of small crystals rather than a small number of large crystals. It also supplies an essential constituent to the crystallizing mineral.

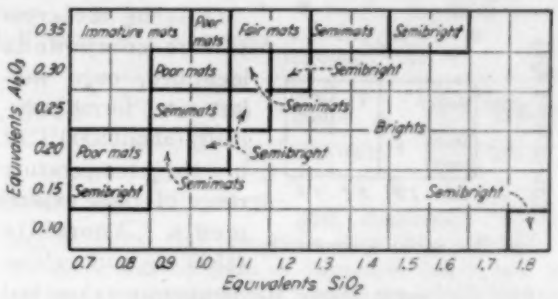

FIG. 12.—Series C, cone 6.

(4) Barium has a similar effect in that it tends to produce a large number of small crystals and also probably furnishes an essential constituent to a crystallizing mineral (celsian), if it forms as suspected.

(5) Good mats form under proper conditions with low alumina and high silica. The Al_2O_3:SiO_2 ratios for mats in each series are as follows: Series P, 1:4 to 1:4.5; Series A, 1:4 to 1:5;

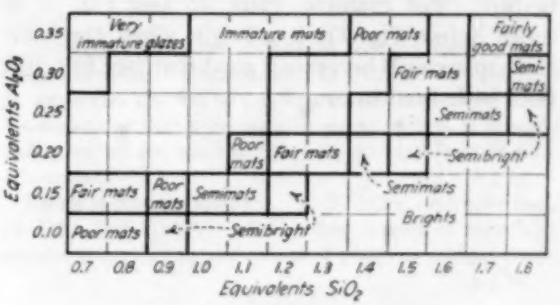

FIG. 13.—Series D, cone 6.

Series B, 1:4.5 to 1:6; Series C, 1:3 to 1:4; Series D, 1:4.5 to 1:6. The mats studied in general fall in the area Al_2O_3:SiO_2, 1:3 to 1:6. Some semimats, semibrights, and even brights depend upon the RO members used.

(6) The zinc compounds present in the raw lead glazes do not crystallize out, but form a glass when the ZnO content is 0.3 equivalent or less.

(7) The CaO introduced seems first to form anorthite and any left over goes to form wollas-

tonite and glass. Wollastonite is more frequent in the low alumina high silica field.

(8) Tridymite was observed in some semimats and in mats low in alumina and high in silica.

(9) Bright spots in mats seem to be due to quartz partially inverted to tridymite surrounded by an envelope of glass.

(10) Anorthite, as suggested by Purdy,[6] and perhaps celsian seem to form first.

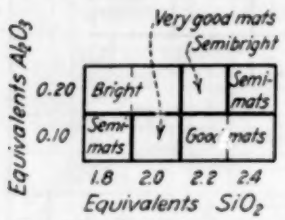

FIG. 14.—Series S, cone 4.

(11) Of the crystalline compounds identified, only wollastonite forms normally (about 1000°C)[15] in the temperature range of these experiments. Anorthite (1550°C) and celsian (1640°C)[15] form above the temperatures reached in systems of the three components involved. It is believed that these compounds could form at the temperatures of this experiment because of the other oxides present, especially PbO which is a strong flux.

(12) The only series which contain the same RO oxides, but in different amounts, are series A and series B. In these, BaO increased at the expense of PbO from 0.1 equivalent in series A to 0.3 equivalent in series B. The effect for a given Al_2O_3:SiO_2 ratio was to increase the mat texture. For example, glaze 33 (see Fig. 1) in series A (see Fig. 11) is a bright glaze, the same glaze in series B becomes a good mat (see Fig. 10); both were fired to cone 6.

VI. Conclusions

The results of this investigation seem to justify the following conclusions:

(1) Crystallization is responsible for the characteristic texture of all the glazes in the mat and semimat areas.

(2) A high alumina content is not essential for matness in these glazes as stated by Binns.[3]

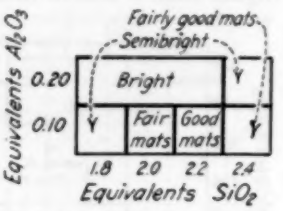

FIG. 15.—Series S, cone 6

(3) In mat glazes containing lime, the principal crystals are anorthite. Wollastonite is less common, but more of it occurs in the low-alumina high silica field.

(4) When zinc oxide is under 0.3 equivalent no zinc silicate crystallizes out, but the zinc combines with the other constituents to form a more fluid glass.

(5) Barium tends to form mats by crystallizing out as a mineral believed to be barium feldspar.

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CERAMIC ABSTRACTS[1]

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Abrasives

Polishing pastes. Henry R. Power. *Metal Cleaning & Finishing*, **5** [12], 519–20 (1933).—A discussion of the composition and application of various types of polishing and abrasive pastes is presented. E.J.V.

Polishing sleeves with Turkish emery abrasive. Cleveland Container Co. *Platers' Guide*, **29** [10], 21 (1933).—Illustrated. E.J.V.

Gem stones. W. T. Gordon. *Nature*, **132** [3329], 267–70 (1933).—Gems and their enhancement by proper cutting and polishing are considered. See also *Ceram. Abs.*, **12** [6], 214 (1933). J.L.G.

Polishing abrasive efficiency. Fred B. Jacobs. *Abrasive Ind.*, **14** [12], 12–13 (1933).—The selection of polishing grain and the manner in which it is tested are cited as two factors that cause inefficiency in the polishing room. J. describes tests and tells how to gage results. A.J.M.

"Jiffy" expanding abrasive and polishing wheels. Joseph L. Howland. *Platers' Guide*, **29** [3], 21; [6], 24 (1933); *Amer. Machinist*, **77** [24], 766 (1933).—These wheels consist of two inwardly sloping flanges and a heat-resisting reinforced rubber cushion band also sloped on the inside. Abrasive bands may be slipped over the rubber cushion and the flanges are placed in the rubber and mounted on the spindle. Tightening of a spindle nut expands the band to hold the abrasive band firmly. Sizes range from 4 to 14 in. in diameter and from $1^1/_2$ to 4 in. face. Illustrated. E.J.V.

Surface grinding machine. Norton Co. *Metal Cleaning & Finishing*, **5** [12], 521 (1933). E.J.V.

Surface grinder. Abrasive Machine Tool Co. *Metal Cleaning & Finishing*, **5** [12], 522 (1933). E.J.V.

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Progress in abrasive tools. Anon. *Abrasive Ind.*, **14** [12], 25 (1933).—Internal grinder, tool-room surface grinder, lapping wheels for cemented carbide, wheel dressers, grinding machines, and spindles for a new surface grinder are described. Illustrated. A.J.M.

Standard types of grinding wheels. Anon. *Amer. Machinist*, **77** [13], 405–406; [14], 437–38 (1933).—Tabulated data are given on dimensions, shapes, etc., of the various grinding wheels listed in Simplified Practice Recommendation R43–32. Illustrated. E.J.V.

Boring and grinding of iron, copper, and aluminium alloys. H. Schallbroch. *Z. Metallkunde*, **24** [12], 308–309 (1932).—Two fundamental questions in obtaining a tight fit in boring and grinding are as follows: (1) How great is the axial pressure and the rotation moment and how do they change under different cutting conditions? (2) What is the difference between mean boring diameter and mean tool diameter and how do they vary under different cutting conditions? Tests were made on all types of alloys of the category listed. The results are summarized in numerous tables and graphs. L.T.B.

Grinding universal joint parts. Cleveland Steel Products Co. *Abrasive Ind.*, **14** [12], 6–7 (1933).—Illustrated. A.J.M.

Grinding supersedes milling in forming tools. H. J. Chamberland. *Abrasive Ind.*, **14** [12], 10–11 (1933).—C. advocates the use of grinding wheels in forming tools. He maintains that a saving of from 40 to 50% is possible and describes the manufacture of a dovetail forming tool. Illustrated. A.J.M.

Safety in modern program. C. B. Auel. *Abrasive Ind.*, **14** [12], 8–9 (1933).—A. describes classes of industrial accidents in grinding and means of guarding against them. A.J.M.

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Device for adjusting cylinder hones, etc. W. E. HEUER (Hall Manufacturing Co.). U. S. 1,941,837, Jan. 2, 1934.

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Tools for truing or refacing grinding disks intended especially for grinding spline shafts. F. WERNER AKT.-GES. Brit. 403,306, Dec. 29, 1933.

Art and Archeology

Researches on the coloring of glass by cementation: red by copper. A. LECRENIER, P. GILARD, AND L. DUBRUL. *Rev. belge ind. verrières, céram., émail.*, **4** [11], 242–46 (1933).—The process of cementation of glass into red by copper salts is still hypothetical. There are two explanations: (1) the red coloring may be due to cuprous oxide. The appearance of a dull red in some samples is caused by too great a reduction of cuprous salts with an appearance of metallic copper. The beautiful transparent red coloring is the preceding stage and results from a reduction of cupric oxide introduced in the surface layer of the glass during the oxidizing firing. (2) The red coloring is attributed to an ionic exchange followed by a reduction into the metallic state. Under the influence of the temperature, copper ions are diffused in the glass and replace alkaline ions in their combinations. Due to these ionic mutations, cupric compounds are formed in the surface layer of the glass, or, more often, a mixture of cupric and cuprous compounds is formed which produces (by reduction) finely divided metallic copper. This gives the glass its coloration, like metallic gold and silver. The color tone obtained depends on the particle size. The dimensions of copper particles are determined by several factors, chiefly the duration of melting and its temperature. Modifications of structure produced by a prolongation at the temperature of cementation may have a certain effect also. An index of literature dealing with the subject is given. For previous abstract see *Ceram. Abs.*, **13** [2], 28 (1934). M.V.K.

Red as glaze and decoration color. F. W. CORDT. *Keram. Rund.*, **41** [24], 307–10 (1933).—C. discusses the preparation of (1) chromium red glaze, (2) uranium red glaze (semi-opaque, very bright, dull glazes), (3) coral-red glaze, (4) gold-purple glaze, (5) Chinese red reduction glaze, (6) leadless Chinese red glaze, (7) underglaze red painting, (8) pink glaze, (9) dark red glaze, (10) purple for tin glazes, (11) white tin glazes, and (12) golden engobe. M.V.K.

Engobe and engobe painting in pottery. ANON. *Keram. Rund.*, **41** [20], 252–54 (1933).—Different kinds of engobes and their application on bodies are described. M.V.K.

Overglaze painting. ANON. *Keram. Rund.*, **41** [26], 336–37 (1933).—Several flux batches are given and discussed. Besides the usual colors, preparations of gold, silver, and platinum are employed. The mixing and firing are described. M.V.K.

Observations on crystal glazes. ANON. *Keram. Rund.*, **41** [28], 361–62 (1933).—A detailed account of observations made on crystal glazes for white wall plates and produced in circular kilns is given. Details in color tones obtained with additions of copper oxide, cobalt oxide, pyrolusite, sodium uranate, nickel oxide, and iron oxide are described. M.V.K.

Etching glass. ANON. *Keram. Rund.*, **41** [21], 271–72 (1933).—This is an excerpt from the Pocketbook for Ceramists, 1933 (*Ceram. Abs.*, **12** [4], 176 (1933)). M.V.K.

Modern potter turns to the East. ANON. *Christian Sci. Mon.*, **26** [18], 7 (1933).—Bernard Leach, Cornish potter of St. Ives, England, has made a study of the methods of the Far East potters and has been producing pottery with adaptations of their traditions in the decoration. Illustrated. E.J.V.

Display in the pottery trade. ROWLAND H. AWMACK. *Pottery Gaz.*, **59** [679], 75–81 (1934).—Illustrated. E.J.V.

Ceramics as a mirror of the culture of nations. J. GR. *Keram. Rund.*, **41** [30], 387–90 (1933).—The character of pottery produced by different countries of the past and present is discussed. M.V.K.

Hohokam: A chapter in the history of red-on-buff culture of Arizona. CARL TRISCHKA. *Sci. Monthly*, **37**, 417–33 (1933).—The camp sites discovered by W. Mardon of Bisbee in 1929 have been further studied by T. Illustrated with pottery designs and photographs. H.H.S.

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Roman and Castor ware in Britain. M. R. HULL. *Illus. London News*, **183**, 473 (1933).—Excavations at Colchester have revealed, among Samian and other pottery, remarkable specimens of the ware called Castor from the Northamptonshire site where several kilns were found. H.H.S.

Prehistoric pottery in England. L. A. VIDLER. *Sussex Archaeol. Collections*, 74 (1933); *Notes & Queries*, **165**, 271–72 (1933).—Kilns and pottery of types not found before in England have been unearthed near Rye. One series of designs is incised upon the soft clay; another type is sun-dried, painted white, and ornamented in red. H.H.S.

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First authentic discoveries in the Arabian realm of the Queen of Sheba. R. TÜNGEL. *Illus. London News*, **183**, 536–37 (1933).—A German expedition to southwest Arabia has identified Yemen with the ancient land of Punt. 11 photographs. H.H.S.

Knowledge of early Chinese culture revolutionized. W. C. WHITE. *Illus. London News*, **183**, 698–701 (1933).—Discoveries in Honan provide concrete evidence of highly developed art in the 5th and 6th centuries B.C. previously known only from literary sources. Illustrated. H.H.S.

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Presence of manganese in Portland cement. O. GOFFIN AND G. MUSSGNUG. *Zement*, **22** [17], 218–21; [18], 231–34 (1933); abstracted in *Chim. & ind.*, **30** [5], 1107 (1933).—Manganese may replace iron in Portland cement but its content should not exceed 5% so that the resistance of the cement will not be lowered. Cement containing Mn_2O_3 is dark gray; that containing MnO_2 is black-gray. Brown or pink colorations indicate a low degree of oxidation. The microscopic examination revealed the presence of two constituents, the brown or black celite and the colorless alite. M.V.K.

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Electrical properties of calcite. S. SHIMIZU. *Sci. Repts. Tôhoku Imp. Univ.*, **22** [3], 570–98 (1933).—Specimens of Japanese calcite, cut parallel and perpendicular to the *c*-axis, were investigated to compare their electrical properties with those of Iceland and Canadian calcites. The residual charge, the after-effect on the conductivity, and the variation of the conductivity with the tempera-

ture have been determined, especially in the range from 500 to 900°C. The measurements of the residual charge and its recovery time show that there is no condensed polarization in the Japanese calcite. The electrical conductivity varies in the temperature range from 680 to 850°C for the sample cut parallel and in the range from 815 to 840°C for the sample cut perpendicular. The dissociation temperature is well defined from the size of the electrical conductivity. W.M.C.

Enamels

Knowledge of clays employed in enameling. W. DAWIHL. *Keram. Rund.*, **41** [29], 374–76 (1933); abstracted in *Emailwaren-Ind.*, **10** [44], 359 (1933).—A detailed account of chemical and physical investigations made on a number of clays employed for enameling is given. It was found that they have an average plasticity and are similar to clays employed for the manufacture of stoneware. The analyses by elutriation, shrinking on drying, and strength on drying give bases for valuating clays. M.V.K.

Lime as an enamel raw material. RICHARD ALDINGER. *Ceram. Ind.*, **21** [3], 118 (1933); for abstract see *Ceram. Abs.*, **13** [2], 32 (1934). E.J.V.

Employing Seger cones for determining the fusibility of enamel. W. DAWIHL. *Keram. Rund.*, **41** [22], 279–80 (1933); abstracted in *Emailwaren-Ind.*, **10** [44], 359 (1933).—Methods for determining the fusibility of enamel including (1) the determination of the heating and cooling curves, (2) the American "button test," and (3) determining the fusibility by means of cone testing bodies (Simpson, *Jour. Amer. Ceram. Soc.*, **13** [1], 69 (1930)) are discussed. Experiments made by using Seger cones as comparison and standard material for measuring fusibility of a ground enamel with and without clay are described. It was found that the employment of cones for determining the fusibility of enamel represents a reference system of general validity. M.V.K.

Method for determining the pore space in enamel. W. DAWIHL. *Keram. Rund.*, **41** [31], 406–407 (1933); abstracted in *Emailwaren-Ind.*, **10** [44], 359 (1933).—It is possible to determine the total volume of pores and to a certain degree the size of pores from the volume weight of a granulated enamel frit and the specific gravity of various finer grains according to the method employed for determining true porosity in ceramics. It is shown by examples that the size of pores determined according to this method agrees in order of magnitude with the sizes of pores determined microscopically. M.V.K.

Essential factors for one-coat finishes. W. H. PFEIFFER AND H. L. COOK. *Enamelist*, **11** [3], 19–20 (1933).—P. states that production of ware with one finish coat requires extreme care in the selection, preparation, and application of the cover-coat enamel as well as the proper preparation of the ground-coated ware and gives a detailed discussion of the various factors. C. discusses the metal shape, the ground coat, the white coat, the spray guns, wiping, and the quality expected. E.J.V.

Ground-coat studies. IV. Consistency and enamel fineness. E. P. CZOLGOS. *Better Enameling*, **4** [12], 15–19 (1933).—To determine the effect that milling to different degrees of fineness has on the consistency and physical properties of ground-coat enamels, a study of a number of ground-coat enamel slips milled to various degrees of fineness was made. It was found that (1) the consistency and physical properties vary with the degree of fineness; (2) relatively coarse slip has a short period of workability, orange peel drain texture developing within a few days and rapidly changing to double drain; (3) finely milled slip will not have a marked orange peel drain texture until the enamel has almost entirely lost its set but will drain poorly when fresh and has a tendency to slide and hang in spots rather than drain cleanly; on large ware it will fire off very easily along the edges; and (4) the drain time of the ground-coat slip, although controlled by the set, is also influenced by the fineness of the frit particles. The coarser the enamel the shorter is the drain time. For Part III see *Ceram. Abs.*, **13** [2], 31 (1934). E.J.V.

Composite expansion curves. ANON. *Amer. Enameler*, **6** [8], 6 (1933).—A description of a test run to determine how each enamel affects the expansion of the other and how the steel affects the whole by obtaining an expansion curve on a composite of steel, ground coat, and two white coats is given. A comparison of a calculated curve with the actual determined curve is presented. E.J.V.

Effect of water hardness on porcelain enamel. E. G. PORST AND H. G. WOLFRAM. *Amer. Enameler*, **6** [8], 3–5 (1933).—A standard ground-coat enamel was milled using different degrees of hardness of natural water in combination with various percentages of setting-up salts such as borax and soda. Results of tests of adjusted slips with a consistometer showed that yield and mobility values vary irregularly when various degrees of hardness of water containing added borax are used as mill waters. Yield values decrease with increased hardness of water up to 237 parts per million, beyond which they increase. Mobilities decrease, increase, and then decrease again, in cyclic fashion, as water hardness is raised. The mobility is marked at the "237 p.p.m. point." E.J.V.

Accounting for porcelain enameled products. II. CHARLES S. PEARCE. *Enamelist*, **11** [2], 10 (1933).—Examples of calculations are given. **III.** *Ibid.*, **11** [3], 11–12 (1933).—When pieces of material are bought by weight and used by the piece, differences in weight may cause differences in costs. Examples of how such differences should be taken into account are given. As it occasionally becomes necessary to run obsolete equipment to keep production up to schedule, some method must be available to the accountant to determine the extra cost of work produced on this higher labor cost equipment. Examples of such accounting are given. For Part I see *Ceram. Abs.*, **13** [1], 7 (1934). E.J.V.

Explaining the expansion in sheet-iron enamel. A. DIETZEL AND K. MEURES. *Sprechsaal*, **66** [44], 746–52 (1933).—(1) There is a principle in enamel practice (since the investigations of Mayer and Havas) that the coefficient of expansion for ground enamels should amount to 245–290 $\times 10^{-7}$ and for cover enamels 320–340 $\times 10^{-7}$, so that

an enamel with a coefficient of expansion of 380–420 $\times 10^{-7}$ (new research shows 360 $\times 10^{-7}$) will fit the iron. A clear explanation for the exceptionally low coefficient of expansion of the ground enamel and the fact that an increase of this coefficient of expansion to about 320–330 $\times 10^{-7}$ produces hairlines was not obtained. (2) In research made previously on adaptation, the coefficient of expansion of enamel (ready to be applied) or of the enamel frit was taken as a basis of comparison instead of that of the fired enamel. (3) The dissolving of greater amounts of iron oxides (20 to 40% for 100% enamel in the deeper layers and 10 to 15% in the upper layers) greatly changes the coefficient of expansion (0° to softening temperature) of the ground enamel. On the basis of expansion measurements of enamel melts with intentional additions of iron oxide, it is shown that the coefficient of expansion of a melted ground enamel of good quality (between 0° and the softening temperature) is slightly less than that of the iron near the iron sheet and that it markedly decreases within the ground enamel layer when approaching the coating enamel in order to be brought nearer to the lower coefficient of expansion (0° to softening temperature) of the coating enamel. (4) The cracking of the ground coat is explained on the basis of this new fact. (5) The old coefficients of expansion (Mayer and Havas) have recognition only as orientation figures ("expansion figures") and are not an explanation for the adaptation of enamel to iron. M.V.K.

Modern method of frit manufacture and control. II. Frit testing. ANON. *Better Enameling*, **4** [12], 10–13 (1933).—Testing procedure with white frits for sheet iron and steel embodies determination of color, texture, luster, opacity or covering power, workability, resistance to impact, cross-bend strength, resistance to thermal shock, coefficient of expansion, and weathering properties. Special frits must be subjected to special tests to prove their suitability and to meet the unusual conditions that they may be called upon to meet. Cast-iron frits also must be subjected to strict tests to insure production of high quality frit. Illustrated. For Part I see *Ceram. Abs.*, **13** [2], 32 (1934). E.J.V.

Pickling method in enamel works. R. ALDINGER. *Keram. Rund.*, **41** [20], 254–55 (1933).—A. discusses the process of pickling. The addition of special colloidal materials, *e.g.*, glue, agar-agar, basic tar-oils, etc., prevents the dissolving of metallic iron by acids but is defective because it lengthens the pickling time and usually prevents a thorough pickling of the raw ware. M.V.K.

Testing apparatus and investigating methods for enamelware. VIELHABER. *Emailwaren-Ind.*, **10** [45], 362–63 (1933).—The chief properties which should be tested in enamelware are (1) appearance (uniformity of surface, color or opacification, and luster), (2) impact strength, (3) flexibility, (4) resistance to mechanical wear, (5) resistance to chemical wear (stability to acids or resistance to acids), and (6) resistance to sudden changes of temperature (boiling strength). It is difficult to define numerically the appearance of the enamel. A reflection meter is used for measuring opacity although it is doubtful that it determines opacity correctly because of the effect of the luster on the reflection. The falling hammer and pendulum are used for determining the impact strength. When testing flexibility, the enamel adherence is observed. The resistance to mechanical wear is one of the most important properties of the enamel, especially that used on cooking utensils. Mechanical cleaning media should not be harder than the enamel; most of the cleansing agents found on the market also have a chemical action. For testing chemical resistance there is a number of proposals but most of them are unsatisfactory. The difficulty of such tests lies in the determination of the "possibility of attack" and in the fact that all tests require complicated and special apparatus. The boiling strength for enameled household ware is important; however, there are no adequate methods for testing it with certainty. The problem is not simple because the shape of the bottom, the thickness of the sheet iron, the kind of enamel, and the thickness of the enamel coat are closely interrelated. M.V.K.

Chief working methods and installations in enameling. ANON. *Sprechsaal*, **66** [9], 147–48; [14], 233–35; [22], 371–72 (1933).—A discussion is given on (1) the grinding of enamel and grinding contrivances, (2) the wet and powder methods and drying of the applied enamel, and (3) the firing of the enamel and the devices used. *Ibid.*, **66** [29], 490–91 (1933).—Details of the firing and muffle furnaces are described. M.V.K.

Unique methods of enameling odd shapes. ANON. *Ceram. Ind.*, **22** [1], 34 (1934).—Due to the complicated shapes presenting a difficult cleaning problem, a scaling or annealing furnace with a conveyer is used to burn off the grease instead of the usual cleaning operation. Dipping of ground coat is done next to the drier, and the overhead drier conveyer chain passes over the dipping tank so that the ware drains as it progresses to the drier. Conveyers add to the plant capacity. A U-type continuous furnace fired with natural gas has been found to be economical in the plant of the Perfection Stove Co., Cleveland, Ohio. Illustrated. E.J.V.

Design of jigs and fixtures for welding. I. OWEN C. JONES. *Better Enameling*, **4** [9], 12–14 (1933).—Fundamentals of design of jigs and fixtures are listed. **II.** *Ibid.*, **4** [10], 8–9 (1933).—Several types of jigs are discussed. **III.** *Ibid.*, **4** [11], 12–13 (1933).—Control of heating effects from the blowpipe flame is a matter of importance in the design of jigs and fixtures for welding. Four ways of handling the expansion problem are given. Operation and regulation of production is discussed at length. Illustrated. E.J.V.

Cupola *vs.* electric melting of gray iron in a specialty foundry. E. A. WISE. *Metals & Alloys*, **4** [6], 75–78 (1933).—The electric furnace is replacing the cupola in foundries where the output must be made from special iron. Illustrated. R.H.H.P., JR.

Quality enamel for the jeweler's art. J. F. BULLARD. *Brass World & Platers' Guide*, **28** [11], 227–28 (1932).—A description of improved gas-fired furnaces developed to solve problems in high-temperature fine enameling work is presented. Illustrated. E.J.V.

Tubs, sinks, and tile give wide background in enameling. ANON. *Ceram. Ind.*, **22** [1], 13–16 (1934).—A detailed description of the plant and products of the Youngstown Pressed Steel Co., Warren, Ohio, is given. Some of the unusual equipment developed to meet particular needs is also described. Illustrated. E.J.V.

Modern fixtures for bringing business. ANON. *Better Enameling*, **4** [12], 6–7 (1933).—Examples of pickup in business resulting from the installation of modern porcelain enamel fixtures in two eastern meat markets are given. Illustrated. E.J.V.

Employment of women in vitreous enameling. ANON. *Amer. Jour. Pub. Health*, **23** [4], 370–71 (1933).—The health conditions of women workers in 50 vitreous enamel plants were studied. Most of the women were young, with three-fourths of them under 30. Where leadless enamel is used there is no definite hazard, but where lead enamels are used the sprayers have more ill health than brushers. Strict medical supervision and furtherance of leadless enamel use are recommended. E.J.V.

Enamel. I-II. W. MAYOR. *Clay Prod. News*, **6** [11], 4–6; [12], 4 (1933).—A historical discussion of art enameling is given. A.J.M.

Early chemistry and chemists in the iron and steel industries. III. L. W. SPRING AND L. E. GILMORE. *Metals & Alloys*, **4** [3], 33–36; [4], 45–48; [5], 65–67 (1933).—A historical sketch of scenes around the early blast furnaces is given. Illustrated. R.H.H.P., JR.

PATENTS

Concealed fastener for wall brackets. E. A. SMITH (American Enameled Products Co.). U. S. 1,940,888, Dec. 26, 1933.

Glass

Recent studies of the fundamental processes underlying glassmelting. W. E. S. TURNER. *Jour. Amer. Ceram. Soc.*, **17** [2], 21–25 (1934).

Methods of determining the constitution of glasses. ERIC PRESTON AND W. E. S. TURNER. *Jour. Amer. Ceram. Soc.*, **17** [2], 26–33 (1934).

Thermal endurance of glass. KOZO TABATA AND TARO MORIYA. *Jour. Amer. Ceram. Soc.*, **17** [2], 34–37 (1934).

Essentials of glass technology based on American practice. V. S. R. SCHOLES. *Ceram. Ind.*, **22** [1], 29–32 (1934).—Beginning the discussion of combustion and fuels, S. takes up temperature, pyrometers, the transfer of heat, the generation of heat, electrical heat, and combustion. Illustrated. For Part IV see *Ceram. Abs.*, **13** [2], 34 (1934). E.J.V.

What is glass? W. E. S. TURNER. Presented at meeting of Society of Glass Technology, Dec., 1933, London; *Pottery Gaz.*, **59** [679], 84 (1934). E.J.V.

Radiation of energy through glass. J. L. BLACKSHAW AND F. C. HOUGHTEN. *Heating, Piping, & Air Conditioning*, **5** [10], 523–25 (1933).—The authors find that glass does not transmit low-temperature radiation which confirms the earlier conclusions of Miller and Black. Ordinary double-strength window glass transmits no measurable amount of radiated energy from a source at 500°F or lower. Only 6.0 and 12.3% of the total radiation is transmitted from surfaces at 700 and 1000°F, respectively. However, glass transmits 76.3% of the total radiation from an incandescent tungsten lamp, 65.7% from an arc lamp, and 88.9% from the sun. Therefore, glass windows are heat traps which allow relatively free transmission of the radiant energy from the sun into the room to warm it but prevent the transmission of re-radiated heat from objects in the room out through the glass. Illustrated. J.L.G.

X-ray diffraction and the study of glasses. J. T. RANDALL AND H. P. ROOKSBY. *Jour. Soc. Glass Tech.*, **17** [67], 287 (1933).—Earlier results on the diffraction of X-rays by glasses have been extended to include vitreous cadmium pyrophosphate, selenium, lithium, metaborate, antimony and bismuth sesquioxides, lead metasilicate, and a number of the more common glasses in everyday use. Figures are given for the band spacings of all glasses so far examined. In agreement with the previous work it is concluded that the diffraction bands can, in general, be explained on the basis of the idea of minute crystals or groups of atoms regularly arranged over small volumes. The reasons for the formation of glasses are discussed in the light of the new experimental work. It is suggested that the probability of the formation of a glass is high for those substances whose normal crystalline forms are such that the forces binding the atoms together are either strongly directional or localized in character. The possibilities of understanding the patterns of the more complex commercial glasses are discussed. It is thought that the regular groups of atoms may not be so definite in composition or size as in the case of the simpler glasses. The connection between this work and the problem of the melting of solid bodies is brought out and suggestions are made. Illustrated. C.H.T.

X-ray investigation of tridymite glass. M. E. NAHMIAS. *Nature*, **132** [3344], 857–58 (1933).—N. finds from X-ray investigation that the crystallites in devitrified glass in the region *B* of the phase diagram of the system, SiO_2–Na_2O–CaO, are tridymite as thought by G. W. Morey and not cristobalite as favored by A. Dietzel (*Ceram. Abs.*, **11** [7], 407 (1932)). Devitrified glass of the initial percentage composition SiO_2 78, CaO 12, and Na_2O 10 (glass *B*) gives an unmistakable tridymite pattern (Co–K_α–50 m.a.h.). J.L.G.

Effect of heat treatment on the expansivity of a Pyrex brand glass. J. B. SAUNDERS AND A. Q. TOOL. Bur. Stand. *Jour. Research*, **11** [6], 799–810 (1933); R.P. 626.—Heating a Pyrex brand glass at different temperatures between 450 and 750°C caused its mean linear expansivity between 20 and 200°C to change more than 10%. This expansivity was approximately 0.0341×10^{-4} in the case of the original untreated specimen, and after treatment at temperatures near 750°C it increased to 0.0345×10^{-4}; treatments at 450°C reduced it to 0.0307×10^{-4}. After any such changes the original expansivity could be restored by a heat treatment near 650°C. Treatments between 650 and 450°C appeared to reduce expansivity steadily as the treating temperature was lowered. These results indicate that there is some advantage in annealing this glass at the lowest practical annealing temperature since any reduction in expansion should increase the resistance of the glass to heat shock. R.A.H.

Diffusion of silver and copper in glass. JOSEF HALBER-

STADT. *Z. anorg. allgem. Chem.*, **211** [1–2], 185–94 (1933).—From the Nernst distribution law it was deduced that metals dissolve in glass in a monoatomic state. The diffusion constant for silver and its temperature coefficient were determined. The diffusion constant is abnormally high showing that silver apparently exists in glass as a solvent. The diffusion constant for copper was also determined. Copper is similar to silver in its diffusion into glass. L.T.B.

Palette of modern colloidal colors. E. ZSCHIMMER. *Céram., Verrerie, Email.*, No. 3, pp. 119–21; No. 4, pp. 203–206; No. 5, pp. 255–59 (1933).—Z. presents a survey of modern colloidal coloration including practical and theoretical discussions. Silver colloidal coloration of glass is dependent upon the temperature, contact between the silver preparation and the glass, the kind and surface of the glass, and the method of preparation of the silver compound. Schulze advances the theory that silver ions are introduced into the glass only at a loss of sodium ions. It is found that several elements, including boron, carbon, silicon, titanium, bismuth, molybdenum, and tungsten, are also able to form colloidal dispersions called "vitrosols" with glass as the dispersing medium. The most important is cadmium selenide which is used in the presence of cadmium sulfide as a decolorizer and as a colorant for selenium ruby glass. Several batches for this glass are given and discussed. M.H.B.

Notes on the manufacture of colorless glasses. No. 20. Annealing. ANON. *Glass*, **10** [10], 404–407 (1933).—This article deals with compressive stresses deliberately induced to strengthen the ware. The three questions treated are (*a*) determination of the existence of stress, (*b*) effect of such stress, and (*c*) process control. A simple strain viewer is described and illustrated. **No. 21. Durability.** *Ibid.*, **10** [11], 448–51 (1933).—The necessity of durability in glasses is emphasized and a compilation and a comparison of numerous tests of durability are given. **No. 22.** *Ibid.*, **10** [12], 492–96 (1933).—The influence of composition on durability is considered and the following materials are compared: (1) sodium and potassium oxides, (2) lime, (3) lead oxide, (4) soda and potash together, (5) barium oxide, (6) magnesia, and (7) zinc oxide. Seven tables giving data are included. For No. 19 see *Ceram. Abs.*, **13** [2], 35 (1934). A.J.M.

Calculation of the approximate chemical composition of glass from the batch. J. A. MARTZ. *Nat. Glass Budget*, **49** [34], 10 (1933).—M. describes the loss in weight of glassmaking materials when heated. A table of factors for converting raw weights to fired weights is given. *Ibid.*, **49** [35], 17 (1933).—Two glass batches are calculated to show the application of the factors. A.J.M.

Glass and its stability. OTTO HERFURTH. *Diamant*, **55** [28], 325–27; [29], 337–38 (1933).—The following methods for determining the attack on glass are described: (1) Weber method for determining the effect of gaseous hydrochloric acid on glass, (2) Mylius method based on the hydrolytic disintegration of glass, (3) Mylius method for determining the alkalis dissolved titrometrically, (4) Keppeler method for testing sheet glass, (5) the grit test method of Kraft, (6) spot sensitivity test of Zschimmer, (7) glass sensitivity to lye, and (8) behavior of glass against acids. M.V.K.

Strength of glass. J. B. MURGATROYD. *Jour. Soc. Glass Tech.*, **17** [67], 260 (1933); *Pottery Gaz.*, **59** [679], 83–84 (1934).—The strength of glass with reference to the surface condition is discussed. Experiments on the thermal endurance of scratched bottles demonstrate that scratches greater in magnitude than those found by Griffith lower the thermal endurance, whereas smaller scratches do not affect this property. Methods of reducing the effect of surface flaws by fusing substances on glass surfaces are also discussed. The strength of glass is dependent on the chance of a surface flaw being correctly oriented to the principal stress, and this theory is applied to the thermal endurance of glass rods. It is deduced that the phenomenon of fatigue under alternating repeated stresses should not be shown by glass and that strong glasses should have weakly defined transition points. The conditions for making a "strong" glass are briefly discussed. Illustrated. C.H.T.

Study of the stresses in flashed glasses. W. M. HAMPTON. *Jour. Soc. Glass Tech.*, **17** [67], 273 (1933).—The results of a mathematical investigation into the stress distribution present in a system consisting of two or more glasses fused together are given. The stress distribution is first worked out for a doublet system where the coefficients of expansion for the two glasses are slightly dissimilar. The two cases distinguished are (1) where the strip is free to bend, and (2) where it is rigidly held at the ends, as this approximates the conditions for the manufacture of such articles as globes. The effect of varying the thickness of the portions of the sheet is discussed, and curves are drawn for the stress distribution showing close agreement with actual photographs taken by means of a Babinet compensator. By a modification of the equations, a method is indicated whereby an estimate of the difference in coefficient of expansion of two glasses can be obtained from a measurement of the curvature of two rods which are drawn together. In the second portion of the paper the distribution is worked out for the case of three glasses fused together; subsequently, the practical case where the two outer glasses are of the same composition and the inner glass of another is given in detail. Typical substances are computed and the results compared with actual photographs. Illustrated. C.H.T.

Behavior of glass when slowly heated with special reference to thermal expansion. ERIC SEDDON AND W. E. S. TURNER. *Jour. Soc. Glass Tech.*, **17** [67], 324 (1933).—Measurements of thermal expansion from room temperature to the softening point in each case have been made on seven glasses differing widely in composition, viscosity, etc. The glasses include fused boric oxide, three soda-silica glasses, two soda-lime-silica glasses, and an extra light flint optical glass of comparatively complex composition. After careful annealing the glasses were heated at the rate of 1° per min. and $^1/_4$° per min. The results show that with special exceptions the extreme difference in linear thermal expansion coefficient of the glasses heated at the two rates did not exceed 4%. With five glasses the transformation point was reduced at the slow rate of heating by an amount which did not exceed 8°. Under similar conditions the softening point was also lowered but in no case could the softening point be reduced to coincide with the transformation point. Transition points at tempera-

tures below 500° were even more noticeable at the slower rate of heating than at the faster rate. In several glasses heat absorption effects caused retrogression in the curve just below the transformation point. Four successive slow heatings of a pure soda-lime-silica glass produced thermal expansion coefficient results differing by not more than 4% over the range 0 to 400°. The conclusion is drawn that while the determinations at slow rates of heating are of special interest in studying the constituents of glass, there is no need for practical purposes for a specimen of 5 mm. thickness to be heated at a rate slower than 1° per min. Illustrated. C.H.T.

Reduction of the alkalinity of soda-lime-silicate glasses by dissolved carbon dioxide. K. Riess and A. Dietzel. *Sprechsaal*, **66** [44], 753–56; [45], 773–75 (1933).—The conditions under which the thread method of Möller and Zschimmer produces recurring values of the hot alkaline solubility were investigated. The alkaline figure can fluctuate ±2% against the mean value for usual soda-lime-silicate glasses in silver-dissolving vessels when the fresh glass melt is obtained in a molybdenum furnace in pure air and homogenized after the melting of the batch through pouring out, crushing, and remelting. In contrast to the formerly prevalent idea, the comparatively large loss of alkalis in the upper layer of a fresh glass melt is due to the vaporization of the alkalis from the last addition of the batch. The result is a different alkaline solubility of the threads from different layers of a fresh glass melt which has not been homogenized before drawing of the threads. The great variation in alkalinity values within different layers disappears after homogenization. Threads of homogeneous glass melts from the Fletcher furnace contain considerably lower alkalinity figures than homogeneous molybdenum furnace threads. The Fletcher furnace glass with smaller alkalinity has higher alkalinity values after remelting and homogenizing of the threads in a molybdenum furnace. The change in alkaline solubility of the glass through the flame gases of the Fletcher furnace reaches to the bottom of the crucible. The lowering of the alkalinity figure with increased effect and duration of the gases of combustion is represented on a diagram; the alkalinity approaches the lowest value and the treated melt approaches a state of equilibrium. The opinion that SO_2-gas has no effect on alkalinity is confirmed; the decreased alkaline solubility is a sequence of the action of CO_2 dissolved in the melt at high temperature. After extracting gas from the threads of a glass containing 15% Na_2O, 10% CaO, and 75% SiO_2, and previously treated with CO_2 for 8 hr. at 1320°, from 2.85 to 3.25 cu. cm. CO (normal) were obtained from 4.8 cu. cm. glass (cold). The escaping amount of CO_2 gas corresponds to 59.0 to 67.5 cu. cm. for 100 cu. cm. glass. The rate of the escape of gas was determined; the state of equilibrium is not reached at 1320° and 1 atmosphere after 8 hr. The CO_2 effect is explained by the assumption that the CO_2 molecules diffused in the melt (because they remain in the cooled glass) obstruct the way for H_2O molecules which penetrate into the glass on dissolving (weathering).

M.V.K.

Physical and chemical processes in melting potassium oxide-lead oxide-silica glass. M. A. Besborodov and G. A. Shinke. *Jour. Soc. Glass Tech.*, **17** [67], 305 (1933).—A study has been made of the process of conversion into glass of a mixture containing potassium carbonate, lead oxide, and silica, calculated to yield a glass of percentage composition SiO_2 48, PbO 45.5, and K_2O 6.5. The progress of reaction on heating at a series of temperatures up to 1200° was followed by the determination of the total loss of weight of the batch with time during heating, the determination of the gases evolved at different temperatures, chemical analysis of the products, and microscopic examination. The tests were applied to K_2CO_3 alone, to the binary mixtures K_2CO_3 + SiO_2, K_2CO_3 + Pb_3O_4, Pb_3O_4 + SiO_2, and to the mixture K_2CO_3 + Pb_3O_4 + SiO_2. The K_2CO_3 employed contained approximately 15% moisture. In the temperature range 100 to 300° there was no indication of any marked reaction other than the liberation of moisture, although CO_2 was freed from the binary carbonate and the ternary mixture. Dissociation of red lead began at 500° and ended at 600°. The K_2CO_3 + SiO_2 reaction became more rapid above 500° and was very rapid at 800°. Microscopic examination showed varying refractive index from point to point even after the reactions were complete. Lead oxide and silica were both dissolved above 1000° and the product was isotropic at 1200°. Illustrated. C.H.T.

Reduction and oxidation of manganese silicates. B. Bogitch. *Compt. rend.*, **196**, 414–16 (1933); abstracted in *Sprechsaal*, **66** [43], 730 (1933).—The melted silicates were treated with gases in two ways. A reduction series, corresponding to MnO, has been obtained with reducing or neutral gases (CO_2, N_2). With a low MnO content, the compounds are colorless; when more than 4% MnO is present, the compounds become green. The oxidation series is formed only in the presence of free O_2, and the colors vary from weak pink-violet to black-violet and black. When Mn_3O_4 is regarded as $MnO_2 \cdot 2MnO$, all the dissociation constituents may be considered as $p MnO_2 \cdot q MnO$; it is possible to proceed in the same way for the silicates of the Mn oxides; p/q, below $1/2$, depends on the temperature, gas atmosphere, and the Mn concentration in the silicate. The amount of oxygen retained by the silicates decreases with (1) lowering of Mn content, (2) increase of temperature, and (3) lowering of the O_2 content of the gas atmosphere. M.V.K.

Using baryta for white cast glass. Anon. *Rev. belge ind. verrières, céram., émail.*, **4** [11], 253–54 (1933).—The difficulties of improving the chemical and physical properties of soda-lime glasses by changing the contents in silica, lime, or soda are discussed and the advantages of using baryta are enumerated as follows: (1) The melting point of mixtures containing it is lowered. (2) Baryta glasses are more fusible than lime glasses at the same temperature and therefore more easily refined. (3) Baryta glasses permit a longer working. (4) The thermal conductivity at high temperature is increased, and the coefficient of dilatation lowered; hence, thermal resistances are increased and the dangers of rupture diminished when adding baryta. Baryta may replace lime advantageously in white glasses, but its content should not exceed 10% of the weight of sand in order not to diminish the resistance to water and atmospheric conditions. To some extent it can replace soda or potash. Two baryta batches are given and discusssed. M.V.K.

Flow of glass in tanks. H. HAUSNER. *Ceram. Ind.*, **22** [1], 18–22 (1934); for abstract see *Ceram. Abs.*, **13** [2], 36 (1934). E.J.V.

Effect of gases on the properties of glass. VI. Effect of heat treatment of glass on its silver plating. K. NAKANISHI. *Jour. Soc. Chem. Ind.* [Japan], **36** [11], 595–96*B* (1933).—A soda-lime and a lead glass were heated respectively in air and in oxygen at, below, or above their softening temperature and silver-plated under the same conditions. The silver plating solution was composed of ammoniacal water solution of silver nitrate and Rochelle salt. It was found that in glasses heated in air below their softening temperature, the reduction of silver proceeded more slowly than in those not heated or heated above their softening temperature. The reduction of silver proceeded most rapidly in glasses heated above their softening temperature and in oxygen. For Part V see *Ceram. Abs.*, **12** [12], 418 (1933). M.V.K.

Preparation and properties of beryllium fluoride glasses. G. HEYNE. *Z. angew. Chem.*, **46** [28], 473–77 (1933).—Glasses were made by melting beryllium fluoride with alkali and alkaline-earth fluorides and a number of other salts including oxides, sulfates, and phosphates. The physical properties of these glasses were studied. Too high an alkali fluoride content causes crystallization in the glass; too little alkali fluoride makes the glasses opal-like. Calcium, magnesium, aluminium, zinc, and titanium fluorides give clear glasses. Glasses made with cobalt fluoride are violet. L.T.B.

Insulating materials manufactured from blast-furnace dust and slag wool. O. KREBS. *Stahl & Eisen*, **53** [43], 1109–10 (1933).—Slag wool is obtained from white fluid slag by the use of water vapor. Thin elastic threads are obtained which are spun into wool. These insulating materials are used in many industries. W.M.C.

Safety glass. Review of the present stage of development. J. WILSON. *Jour. Soc. Glass Tech.*, **17** [67], 296 (1933).—The commercial development of the industry and legislation requiring the use of laminated glass in vehicles are reviewed. An outline is given of the conditions to be fulfilled by a satisfactory laminated glass and the progress of the more important manufacturing process is discussed. Toughened and other forms of safety glass are discussed. C.H.T.

"Pyroptic" inspection window. ANON. *Foundry Trade Jour.*, **49**, 192 (1933); for abstract see *Ceram. Abs.*, **12** [6], 238 (1933). H.H.S.

Tank-block problems. W. MIEHR. *Tonind.-Ztg.*, **57** [92], 1085–86 (1933).—Reasons for the destruction of tank blocks are as follows: (1) normal effects due to operation, such as melting temperature and flow of the melt in the melting and working tanks, hence, mechanical and chemical effects; (2) abnormal effects of operation such as tests with new batches, higher melting temperature, etc.; (3) defects in tank blocks such as unsuitable chemical and physical properties; and (4) effects of construction, *e.g.*, measurements of the tank, position of the burners, insulation or cooling, etc. A brief review of the suitability of some clays and kaolins for use in the manufacture of tank blocks and their working is given. M.V.K.

Guiding lines for building flow in Fourcault tanks. G. NOVÁKY. *Sprechsaal*, **66** [40], 679–80; [41], 697–98 (1933).—After discussing the flow of glass, N. describes (1) the amount of flow in different tanks, (2) injurious effects of large amounts of flow, (3) determination of optimum values for the "figure of flow," and (4) practical regulation of the calculated best "figure of flow." Tables and diagrams illustrate the discussion. M.V.K.

Methods and conditions of controlling the rate of drawing of the glass ribbon in Fourcault machines. N. P. KRASNIKOV. *Keram. i Steklo*, **9** [8], 12–18 (1933).—After reviewing present devices for starting Fourcault machines and regulating their working rate, K. discusses factors affecting the rate of drawing the glass ribbon, *e.g.*, thickness of the ribbon, viscosity of the glass (its composition), the power of drawing, and the power of friction. High quality glass depends chiefly on how these factors are stabilized. M.V.K.

Application of statistical methods to quality control of manufactured products. B. P. DUDDING AND I. M. BAKER. *Jour. Soc. Glass Tech.*, **17** [67], 239 (1933).—Utilizing data obtained in different laboratories from thermal endurance tests on glass rods of various diameters, some of the simpler statistical methods of analysis are illustrated. The principles underlying the determination of limits to be used in quality control charts are considered, and the adaptability of these charts to the scrutiny of routine test data is emphasized. Reference is made to the methods of testing the significance of two estimates of a correlation coefficient. Illustrated. See also *Ceram. Abs.*, **12** [8], 295 (1933). C.H.T.

New art mirror added to Silverman collection. ANON. *Nat. Glass Budget*, **49** [36], 6 (1933).—Illustrated. A.J.M.

Glass rarities for Toledo Art Museum from the E. D. Libbey fund. ANON. *Amer. Glass Rev.*, **53** [14], 22 (1934). A.J.M.

Ware collection of Blaschka glass models of plants. ANON. *Glass Ind.*, **15** [1], 1–3 (1934).—A brief history of the production of this famous Harvard Univ. collection of glass models of plants and flowers in natural colors by Leopold and Rudolph Blaschka, of Aicha, Bohemia, is presented. The specimens made since 1895 are the handiwork of Rudolph Blaschka. As his father's only apprentice, he has retained the secret of his art and has had no assistants or apprentices since his father's death. Illustrated. E.J.V.

Old English glass. No. 46. FRANCIS BUCKLEY. *Glass*, **10** [9], 374–76 (1933).—Old glass lists are given. Illustrated. **No. 47.** *Ibid.*, **10** [10], 417–18 (1933).—Notices from old English papers about glassworks and glassworkers are given. Illustrated. For Nos. 42–45 see *Ceram. Abs.*, **13** [2], 36 (1934). A.J.M.

Modern glassworks costs. I. S. HOWARD WITHEY. *Glass*, **10** [12], 499–500 (1933).—In the first of a series of articles on glassworks cost accounting, W. describes the organization of the purchasing department. A.J.M.

Glass for buildings. VICTOR LÉFEBURE. *Chim. & ind.*, **30** [5], 1240 (1933).—A brief review is given of research made in England dealing with (1) manufacture of glass sheets of large dimensions, (2) progress in glass coloring by certain oxides and rare metals which modify the physical and chemical qualities of the glass, and (3) the fusion of glass with metal. M.V.K.

Glass walls supplied in color. ANON. *Bldg. Supply News*, **45** [2], 60–61 (1933).—Carrara glass, produced by the Pittsburgh Plate Glass Co. and used on bathroom and kitchen walls, exterior facing of store fronts, hospital operating rooms, etc., is manufactured in gray, jade green, ivory, black, and white. Illustrated. E.J.V.

Structural and decorative glass in "space house." ANON. *Amer. Glass Rev.*, **53** [9], 19 (1933).—Illustrated. A.J.M.

Glass in home interior. MADELINE T. LOVE. *Amer. Glass Rev.*, **53** [6], 19 (1933).—Illustrated. A.J.M.

Store front development. F. J. PLYM. *Amer. Glass Rev.*, **53** [12], 19 (1933). A.J.M.

History of plate glass in America. R. INGOUF. *Amer. Glass Rev.*, **53** [11], 9 (1933).—An address presented at the meeting of the National Glass Distributors' Assn. is given in full. A.J.M.

Oklahoma bottle plant. SHERMAN J. KLINE. *Glass Ind.*, **15** [1], 3 (1934).—A brief description of the modern, completely equipped bottle plant of the Liberty Glass Co. at Sapulpa, Okla., is given. E.J.V.

Hollow glassware manufacture in the western U. S. ANON. *West. Machinery & Steel World*, **24** [4], 100 (1933); abstracted in *Sprechsaal*, **66** [40], 683 (1933). M.V.K.

BOOKS

Johann Kunckel (1630-1703). H. Maurach. Reviewed in *Mech. Eng.*, **55** [12], 781 (1933); for review see *Ceram. Abs.*, **12** [8], 295 (1933). F.G.H.

Early Glassmaking in Virginia. MAUDE POLLARD HULL. Price $1.00. *Ceram. Ind.*, **22** [1], 38 (1934).—A history of the glass factories in Virginia in 1608, 1621, and 1666 is given. E.J.V.

PATENTS

Glassblowing machine. ROBERT PATTERSON (Carr-Lowrey Glass Co.). U. S. 1,939,917, Dec. 19, 1933.

Glass rolling apparatus. J. H. FOX AND WILLIAM OWEN (Pittsburgh Plate Glass Co.). U. S. 1,939,967, Dec. 19, 1933.

Process and apparatus for making safety glass. W. O. LYTLE (Duplate Corp.). U. S. 1,939,998, Dec. 19, 1933.

Machine for forming glass articles. L. D. SOUBIER (Owens-Illinois Glass Co.). U. S. 1,940,634, Dec. 19, 1933.

Holder for refractors. T. W. ROLPH (Holophane Co., Inc.). U. S. 1,941,109, Dec. 26, 1933.

Process and apparatus for producing compound glass sheets. BERNHARD ENGELS. U. S. 1,941,392, Dec. 26, 1933.

Glassmelting furnace. VIRGIL MULHOLLAND (Hartford-Empire Co.). U. S. 1,941,410, Dec. 26, 1933.

Regenerative glassmelting furnace and burner control mechanism therefor. VIRGIL MULHOLLAND (Hartford-Empire Co.). U. S. 1,941,411, Dec. 26, 1933.

Apparatus for automatically controlling the weight of glass articles made by the gob feed automatic machine process. K. M. HENRY AND B. A. NOBLE (Hartford-Empire Co.). U. S. 1,941,552, Jan. 2, 1934.

Measuring dispensing bowl or receptacle. W. L. HIGLEY. U. S. 1,941,745, Jan. 2, 1934.

Method and apparatus for making glass. W. O. AMSLER (Simplex Engineering Co.). U. S. 1,941,778, Jan. 2, 1934.

Glass tank. W. O. AMSLER (Simplex Engineering Co.). U. S. 1,941,779, Jan. 2, 1934.

Gas-bulb heating apparatus. A. W. MACHLET. U. S. 1,941,807, Jan. 2, 1934.

Suction gathering bottle machine with overlapping cycles. R. W. CAMFIELD (Hartford-Empire Co.). U. S. 1,941,878, Jan. 2, 1934.

Photoelectric control of glass feeders. E. O. HILLER (Hartford-Empire Co.). U. S. 1,941,896, Jan. 2, 1934.

Apparatus for feeding batch to glassmelting furnaces. E. O. HILLER (Hartford-Empire Co.). U. S. 1,941,897, Jan. 2, 1934.

Apparatus for maintaining the thickness of drawn glass. JULES ARRAULT (Soc. anon. des manufactures des glaces et produits chimiques de St.-Gobain, Chauny et Cirey). U. S. 1,941,924, Jan. 2, 1934.

Process and apparatus for feeding glass. W. J. MILLER AND E. A. LAWRENCE (Hartford-Empire Co.). U. S. 1,942,035, Jan. 2, 1934.

Glass transfer mechanism. S. B. BOWMAN AND THOMAS STENHOUSE (Hazel-Atlas Glass Co.). U. S. 1,942,084, Jan. 2, 1934.

Light signal lens. A. T. CARTER AND E. W. MOORE (General Railway Signal Co.). U. S. 1,942,136, Jan. 2, 1934.

Ophthalmic lens. A. E. GLANCY (American Optical Co.). U. S. 1,942,400, Jan. 9, 1934.

Mirror and process of making. G. F. COLBERT AND W. H. COLBERT (Liberty Mirror Works). U. S. 1,942,686, Jan. 9, 1934.

Optical lens and method of making. H. M. E. SACHS (Robert Malcolm). U. S. 1,942,775, Jan. 9, 1934.

Optical glass. EDWIN BERGER (Jenaer Glaswerk Schott & Gen.). U. S. 1,943,051, Jan. 9, 1934. An optical glass is described in which there exists between the refractive index n_D and the relative dispersion γ the relation $n_D > 1.77 - 0.0037\gamma$, containing 0.5 to 20% titanium oxide, the purpose of the titanium oxide being to reduce the susceptibility of the glass to tarnishing.

Glassworking apparatus. W. L. VAN NESS (Corning Glass Works). U. S. 1,943,195, Jan. 9, 1934.

Method and apparatus for manufacturing tubular glass articles. A. HOFMANN & Co. Brit. 402,306, Dec. 6, 1933.

Method and apparatus for circulating the glass in glass-furnace gathering basins. A. F. MCNISH. Brit. 402,366, Dec. 6, 1933.

Production of vitreous silica ware. F. L. CLARK AND IMPERIAL CHEMICAL INDUSTRIES, LTD. Brit. 402,400, Dec. 13, 1933.

Glass elements for concrete covers, pavement lights, etc. SOC. ANON. DES MANUFACTURES DES GLACES ET PRODUITS CHIMIQUES DE ST.-GOBAIN, CHAUNY ET CIREY. Brit. 402,-641, Dec. 13, 1933.

Apparatus for drawing glass in sheets. NAAMLOOZE VENNOOTSCHAP HOLLANDSCHE MAATSCHAPPIJ VOOR DE VERVAARDIGING VAN GLAS. Brit. 402,690, Dec. 13, 1933, and Brit. 403,033, Dec. 20, 1933.

Manufacture of safety glass. C. W. BONNIKSEN AND PROTECTOGLASS, LTD. Brit. 402,774, Dec. 29, 1933.

Glassware. E. A. HAILWOOD. Brit. 402,874, Dec. 20, 1933.

Structural Clay Products

Classification of florescence. ELLIS LOVEJOY. *Bull. Amer. Ceram. Soc.*, **13** [1], 22–23 (1934).

Contributions to the study of florescences. VI. Florescence test and the chemical examination of florescences. B. BUTTERWORTH. *Trans. Ceram. Soc.* [Eng.], **32** [6], 270–83 (1933); for abstract see *Ceram. Abs.*, **12** [3], 106 (1933); for Part V see *ibid.*, **11** [2], 105 (1932). R.H.H.P., JR.

Thermal conductivity of various insulators at room temperature. C. D. NIVEN. *Can. Jour. Research*, **9** [2], 146–52 (1933).—The values for thermal conductivity of various common materials chiefly used in the walls of houses are given. By plotting the results obtained, as well as those obtained by other investigators, on a density-conductivity diagram there is a general indication that at higher densities thermal conductivity increases with the increase of density much more rapidly than it does at low densities. E.J.V.

Trass lime for constructing roads of hard-fired brick. KARL BIEHL. *Tonind.-Ztg.*, **57** [86], 1016–17 (1933).—Slow setting of the trass-lime mortar makes it insensitive to heavy traffic. Ground moisture will allow trass-lime mortar to set over a long period. The strength of bond between hard-fired brick and trass-lime mortar will be increased by traffic load. W.M.C.

Hard-fired brick used in highway construction. M. VAN BEBBER. *Tonind.-Ztg.*, **57** [89], 1051–52 (1933). W.M.C.

Opportunity of the brick industry in the new home building program. *Bull. Amer. Ceram. Soc.*, **13** [1], 27 (1934).

Clay Products Short Course at Iowa State College. *Bull. Amer. Ceram. Soc.*, **13** [1], 27 (1934).

Practical clayworking. VIII. ANON. *Brit. Clayworker*, **42** [500], 254–56 (1933).—The present article discusses the de-airing of clay, the grogging of clay, re-pressing of wire-cut brick, re-pressing and sand-facing of wire-cut brick, mechanical sand-facing and rustic facings, the manufacture of perforated and hollow brick, the Fletton brick, and the stiff-plastic process. For Parts VI and VII see *Ceram. Abs.*, **13** [2], 39 (1934). R.A.H.

Sewer-pipe industry and its problems. ANON. *Brick Clay Rec.*, **83** [6], 197–98 (1933).—Due to a false sense of security and decreased sales, the sewer-pipe industry has had a low volume of business for the last three years. There is a need to solve problems for improving the quality of the product and for reducing production costs. Conditions that sewer pipe have to meet have changed though manufacturing methods are still the same. De-airing of clay is suggested to obtain better pipe. Other possibilities for improvement are suggested. E.J.V.

Large clay product unit. ANON. *Bldg. Supply News*, **45** [2], 58–59 (1933).—Rainstruck ashlar, manufactured by Poston Springfield Brick Co., is inherently a face brick containing all of the properties of a vitrified clay product, the variations in texture, and practically the full range of color typical of present-day face brick. It is made in different sizes ranging in face measurements from $2^1/_4$ x $3^3/_4$ in. to $7^3/_4$ x $12^1/_4$ in., all units being $3^3/_4$ in. in depth. When the $2^1/_4$ x $3^3/_4$-in. unit is used as a tie to the backing wall it is 8 in. in depth. Advantages are enumerated. Illustrated. E.J.V.

Odd-shaped brick make possible unique combinations. ANON. *Bldg. Econ.*, **8** [3], 11–12 (1932).—A description of some of the possibilities of decorative and versatile uses of Bridal brick, designed by Edward F. Rammer, is given. The primary shape is an elongated hexagon and in all its variations the hexagonal lines are maintained. Illustrated. See *Ceram. Abs.*, **12** [7], 264 (1933). E.J.V.

Tile manufacture from clays sensitive to drying and firing. CARL WEHNERT. *Tonind.-Ztg.*, **57** [91], 1078 (1933).—A discussion of conditions under which clays sensitive to drying and firing may be employed for the manufacture of tile is given. M.V.K.

Difficulties in drying hollow tile. G. B. SINGER. *Tonind.-Ztg.*, **57** [90], 1064–65 (1933). W.M.C.

Reinforced brick masonry imparts new quality to brickwork. HERBERT V. KAEPPEL. *Bldg. Supply News*, **45** [6], 202 (1933).—Reinforced brick masonry imparts a new quality to brickwork which it never had before, that of being able to support loads in tension. Tests have proved the remarkable strength of reinforced brick masonry. The cost of laying reinforced brick masonry is often found to be less than if concrete had been used, due to the use of simpler and less expensive forms. Illustrated. E.J.V.

Reinforced brick masonry. HUGO FILIPPI. *Bldg. Econ.*, **9** [1], 6–9 (1933).—A brief description is given of full size field-test structures, with a general statement of their behavior under load. Illustrated. E.J.V.

America's first major structure of reinforced brickwork. HUGO FILIPPI. *Bldg. Econ.*, **8** [2], 6–9 (1932).—A detailed description of the reinforced brick storage bins of the Wedron Silica Co., Wedron, Illinois, is given. Illustrated. See also *Ceram. Abs.*, **10** [11], 779 (1931). E.J.V.

Building 42-foot span of reinforced brick masonry without falsework in record time. JUDSON VOGDES. *Bldg. Econ.*, **8** [3], 6–9 (1932).—A detailed description of a bridge of reinforced brick masonry built on the grounds of the Melrose Country Club, near Philadelphia, Pa., is given. Illustrated. E.J.V.

Building reinforced brickwork in India. MASON VAUGH. *Bldg. Econ.*, **7** [10], 4–6 (1931).—A description of two reinforced brick buildings constructed at the Allahabad Agricultural Institute, Allahabad, India, using the most primitive equipment and very little skilled labor, is given. Excellent construction results were obtained. Illustrated. E.J.V.

Reinforced masonry no costlier than brick veneer. CHARLES H. FORK. *Bldg. Econ.*, **8** [5], 6–9 (1932).—Comparative cost data on a reinforced brick masonry house and a brick veneer house of the same size are presented. Illustrated. E.J.V.

Brick porch demands develop new method of construction in reinforced brick masonry. CHARLES H. FORK. *Bldg. Econ.*, **8** [6], 16–17 (1932).—Wire-mesh reinforcing in a slushy mortar bed and two courses of brick thereon are used for brick porch construction. Illustrated. E.J.V.

Reinforced brickwork floors for porches and terraces. J. F. NICHOLL. *Bldg. Econ.*, **9** [1], 10–11 (1933).—A description of methods of laying reinforced brickwork floors that have resulted in both an attractive and an exceptionally well constructed floor is given. Illustrated. E.J.V.

Brickwork has proved itself through many centuries of service. ANON. *Bldg. Econ.*, **9** [2–3], 19 (1933).—Citing the case of brick walls still standing in Babylon and Ur after nearly 6000 years, the expectation of service of a modern reinforced brick wall should be much greater. The various features which make brick such an enduring building material are enumerated. Illustrated. E.J.V.

Factors affecting the cost of brickwork. L. B. LENT. *Bldg. Econ.*, **7** [8], 15 (1931).—Three principal items of cost, (*a*) brick, (*b*) mortar, and (*c*) labor are discussed in detail. E.J.V.

Highly porous light-weight brick with additions of peat. ANON. *Tonind.-Ztg.*, **57** [92], 1090 (1933).—Advantages of employing peat in the manufacture of porous light-weight brick are enumerated and data on their properties are given. M.V.K.

Brickwork engineering. II. L. B. LENT. *Bldg. Econ.*, **7** [3], 20–21; [4], 20–21; [5], 20–21; [6], 20–21; [7], 20–21; [8], 20–21; [10], 20–21 (1931).—L. discusses the design and construction of those basic structural parts and design considerations which are common to any type or style of building. See also *Ceram. Abs.*, **11** [2], 107–108 (1932). E.J.V.

Exteriors of brick offer beauty in many treatments. ANON. *Bldg. Econ.*, **9** [2–3], 17 (1933).—A brief discussion of exterior treatments of brick walls, consisting of the different handling of the bond and mortar joints and an extensive variety of pattern work, is given. Illustrated. E.J.V.

Brick interiors in natural finish are winning favor. ANON. *Bldg. Econ.*, **9** [2–3], 33 (1933).—Examples of the use of natural brickwork for interior finish in public and private buildings are cited, showing how this idea has been increasingly accepted. Illustrated. E.J.V.

Supervision of brick construction. L. B. LENT. *Bldg. Econ.*, **7** [10], 16–18 (1931).—Three essentials in the production of good brick masonry are good brick, mortar, and workmanship. Proper supervision is not difficult but it is important. Details to be watched are discussed at length. E.J.V.

Calculating the costs in a brick plant. ANON. *Tonind.-Ztg.*, **57** [90], 1060–61 (1933).—Production costs are calculated for a plant with an output of 4 million common brick. Comparison data are given for an output of 75, 50, and 35% normal capacity of the plant. W.M.C.

Limits of rentability in brick plants. ANON. *Tonind.-Ztg.*, **57** [88], 1039 (1933).—This is a discussion of the paper by Schober (*Ceram. Abs.*, **13** [1], 13 (1934)). W.M.C.

Allowances for new buildings and repairs of buildings in Germany. BRÖNNER. *Tonind.-Ztg.*, **57** [85], 1005–1007 (1933). W.M.C.

BOOK

Economic and Manufacturing Aspects of the Building-Brick Industries. A. ZAIMAN AND W. A. MACINTYRE. *Dept. Sci. Ind. Research, Bldg. Research Special Rept.*, No. 20. vii + 111 pp. Published by H. M. Stationery Office, London, 1933. A review of the history of brick and their place in building is given and the types of brick in use are classified as to their (*a*) texture and color, (*b*) modern sizes, weights, and prices, (*c*) effect in housing schemes, (*d*) production, (*e*) exports from and imports into the United Kingdom and other countries, (*f*) competing materials, and (*g*) tendencies in brick development. The plant sizes of various manufacturers, trade associations, and selling arrangements and publicity are discussed. Factors in cost of production are described in detail and transportation and labor condition problems are discussed. The general processes of manufacture are described under (1) raw materials, (2) excavation, (3) weathering, (4) preparation, (5) forming, (6) drying, and (7) firing. Illustrated. C.H.T.

PATENTS

Porous ceramic product and its manufacture. F. E. KERN. U. S. 1,941,804, Jan. 2, 1934. The process of manufacturing porous ceramic products comprises subjecting relatively low-temperature bituminous coal to a distillation whereby volatiles are removed therefrom, comminuting the devolatilized coal and mixing it with comminuted clay material, plasticizing the mixture, forming the plastic mixture into shapes, and subjecting the shapes to heat treatment whereby the coal is burned from the shapes.

Fly ash structural material. H. C. PEFFER AND P. W. JONES (Rostone, Inc.). U. S. 1,942,769 and 1,942,770, Jan. 9, 1934.

Brick building material. P. HOLZMANN AKT.-GES. ZWEIGNIEDERLASSUNG BERLIN. Brit. 402,187, Dec. 6, 1933.

Brickmaking machines. G. H. MAJOR. Brit. 402,197, Dec. 6, 1933.

Refractories

Effect of temperature treatment on abrasives and abrasive products. ROSS C. PURDY. *Jour. Amer. Ceram. Soc.*, **17** [2], 39–42 (1934).

Discoloration of refractories by "iron." J. W. MELLOR. *Trans. Ceram. Soc.* [Eng.], **32** [9], 403–14 (1933); reprinted in *Bull. Brit. Refrac. Research Assn.*, **31**, June, 1933.—The red and buff coring of brick is explained on the basis of a hypothesis of the thermal decomposition of clays at 500 to 600°C. It was found that while ferrous oxide does not ordinarily associate itself with alumina, ferric oxide below 700° forms a solid solution with alumina which can be broken up again at higher temperatures. Discolorations on the surface of lime-bonded silica brick may be produced when the lime is fixed as sulfate by the condensation of dilute H_2SO_4 from the hot kiln gases on the cold brick. Illustrated in colors. R.H.H.P., JR.

Firing magnesite brick. I. J. H. CHESTERS AND C. W. PARMELEE. *Trans. Ceram. Soc.* [Eng.], **32** [8], 349–70 (1933).—In a preliminary study the firing shrinkage of test pieces rammed under a pressure of 10,000 lb./sq. in. was measured continuously by means of an alundum differential expansion system heated in a molybdenum furnace. The results of porosity determinations and the shape of the shrinkage curves for various temperatures showed that increase in density of the magnesia accounted for only a small fraction of the firing shrinkage and that

the main part was caused by the drawing together of the grains by the molten bond. Souring of the batch decreased the shrinkage of test pieces rammed under high pressure. R.H.H.P.,Jr.

British refractories industry: Recent technical improvement. W. J. Rees. *Times Eng. Supp.*, **33**, 79 (1933).—The importance of close jointing in furnace walls, the use of pressures up to 12,000 lb. in pressing the brick, the casting of fused refractories into molds, improved drying methods, and tunnel kilns are described. Provision of specifications for particular types of service, such as the gas industry and glassmelting furnaces, is noted. H.H.S.

Comparison of the rates of flow of water and air through refractory materials. F. H. Clews, E. O. Mills, and A. T. Green. *Trans. Ceram. Soc.* [Eng.], **32** [10], 472–78 (1933); see *Ceram. Abs.*, **12** [7], 266 (1933). R.H.H.P.,Jr.

Action of carbon monoxide on refractory materials. W. Hugill, H. Ellerton, and A. T. Green. Presented at meeting of English Ceramic Society, Nov., 1933, London; *Colliery Guard.*, **147** [3806], 1097 (1933); see also *Ceram. Abs.*, **12** [6], 228 (1933). E.J.V.

Improved method for measuring "after-contraction" of refractory materials. A. E. J. Vickers and J. A. Sugden. *Jour. Soc. Glass Tech.*, **17** [67], 320 (1933).—An improved method consists in standing the test piece on three steel balls on a steel plane table. A steel ball carried at the top of the test piece bears against the plunger of an Ames dial gage, and the gage is standardized against steel rods of known lengths. An accuracy of one unit in the second decimal place is claimed. Illustrated. C.H.T.

Studies of refractory material. XIII. Mullite. Anon. *Refrac. Jour.*, **9** [11], 425 (1933).—The composition and properties of mullite are briefly discussed. **XIV. Diaspore.** *Ibid.*, **9** [12], 459 (1933).—The occurrence and properties of diaspore are discussed. For previous articles see *Ceram. Abs.*, **12** [6], 228; [10–11], 375, 397 (1933); **13** [2], 46 (1934). A.J.M.

Testing refractory materials. Cyril Edwards. Presented at meeting of English Ceramic Society, Nov., 1933, London; *Colliery Guard.*, **147** [3806], 1097 (1933). E.J.V.

Permeability of refractory materials to gases. III. Experiments at temperatures up to 850°. F. H. Clews and A. T. Green. Presented at meeting of English Ceramic Society, Nov., 1933, London; *Colliery Guard.*, **147** [3806], 1096 (1933); see also *Ceram. Abs.*, **12** [3], 111, 112 (1933); for Parts I–II see *ibid.*, **12** [12], 422 (1933). E.J.V.

Special refractories for metallurgical research at high temperatures. Donald Turner. Presented at meeting of English Ceramic Society, Nov., 1933, London; *Colliery Guard.*, **147** [3806], 1096–97 (1933). E.J.V.

Graphite from Passauer for refractory purposes. Erich Buchholtz. *Feuerfest*, **9** [10–11], 140–42 (1933).—B. discusses (1) the requirements for graphite as crucible material, (2) the advantages of Passauer graphite and its deposits, and (3) the development of the Bavarian graphite industry. M.V.K.

Limits of refractoriness. Anon. *Keram. Rund.*, **41** [26], 337–38 (1933).—The melting point and the industrial application of oxides of beryllium, calcium, zirconium, hafnium, magnesium, and thorium are discussed. The melting points of carbides, nitrides, borates, and their mixtures are given. It has been found that a mixture of 4 parts of tantalum carbide and 1 part of hafnium carbide has a melting point of 4215°. M.V.K.

Artificial drying of fire brick. M. S. Kazanskiĭ and P. P. Yagupov. *Keram. i Steklo*, **9** [8], 5–9 (1933).—The economical advantages of artificial drying of refractories for glass furnaces are examined. See also *Ceram. Abs.*, **12** [2], 70 (1933). M.V.K.

Microscopy of silica brick, with special reference to the inversion forms of silica. J. M. Coon. Presented at meeting of English Ceramic Society, Nov., 1933, London; *Colliery Guard.*, **147** [3806], 1096 (1933). E.J.V.

Change of the magnetic and X-ray spectroscopic properties during the change of a mixture of magnesia and iron oxide into spinel. II. Herbert Kittel and Gustav F. Hüttig. *Z. anorg. allgem. Chem.*, **212** [2], 209–13 (1933).—The changes in properties when MgO-Fe_2O_3 is formed were studied. The course of the reaction was followed by means of X-rays. For Part I see *Ceram. Abs.*, **12** [8], 314 (1933). L.T.B.

Refractories. IV. Alfred H. Loveless. *Blast Fur. Steel Plant*, **21** [12], 655 (1933).—The preparation of grog and crushing for use are discussed. The effect of size of grog on properties of the brick is explained. For Part III see *Ceram. Abs.*, **13** [2], 40 (1934). E.J.V.

Magnesite brick in Russia. Anon. *Internat. Bull. Refrig.*, **14**, 321–22 (1933).—Russian production of magnesite in 1931 was 264,000 tons and of magnesite brick, 30,384 tons. H.H.S.

Heat of formation of SiC. Otto Ruff and Paul Greiger. *Z. anorg. allgem. Chem.*, **211** [1–2], 145–49 (1933).—The heat of formation of SiC from α-graphite and crystalline silicon is 26.7 ± 2.1 Cal. L.T.B.

The Bassenheim furnace. H. E. White. *Metals & Alloys*, **4** [6], 89–90 (1933).—A historical sketch is given. Illustrated. R.H.H.P.,Jr.

Electric furnace refractories in the brass foundry. H. M. St. John. *Metals & Alloys*, **4** [12], 183–91 (1933).—The Committee on Nonferrous Survey presents the report on operation and refractory practice received from 63 brass foundries employing the following types of electric melting furnaces: Detroit arc, Repel arc, Ajax-Wyatt induction, and Bailey resistance. It was found that those plants that maintain a furnace lining in constant repair have the lowest total refractory costs. R.H.H.P.,Jr.

Use of standardized brick in furnace construction. E. Maase. *Stahl & Eisen*, **53** [45], 1156–61 (1933).—The new German standard specifications for fire brick and crown tile are discussed. W.M.C.

Factors leading to greater production from a steel furnace. Arthur Robinson. *Refrac. Jour.*, **9** [11], 402–407 (1933).—R. discusses problems which are of general interest and some which have a special bearing on the basic-lined furnace. The factors which control rapidity of working with its attending fuel economy are: (1) furnace design, fettling and repairing practice, heating control, (2) charging and casting facilities, (3) quality of raw materials and their mechanical condition, (4) process and practice, chemical control, and (5) staff. Illustrated. A.J.M.

Refractory lining of coreless induction furnaces. H. Siegel. *Siemens-Z.*, **13** [4], 147–50 (1933); abstracted in

Feuerfest, **9** [10–11], 154 (1933); for abstract see *Ceram. Abs.*, **13** [1], 14 (1934). M.V.K.

Suspended walls for combustion chambers. LIPTAK FURNACE ARCHES, LTD. *Elec. Rev.*, **113** [2912], 346 (1933); for abstract see *Ceram. Abs.*, **12** [8], 306 (1933). J.L.G.

High-frequency furnace linings and results of investigations of several lining failures. J. E. PRIESTLEY AND W. J. REES. Presented at meeting of English Ceramic Society, Nov., 1933, London; *Colliery Guard.*, **147** [3806], 1097 (1933). E.J.V.

Changing position of burners to correct refractory troubles. H. M. SPRING. *Power*, **78** [1], 43 (1934).—The relation of burner installation methods to the life of the refractories used is described and illustrated. F.G.H.

Furnace linings without joints. ANON. *Tonind.-Ztg.*, **57** [89], 1052–53 (1933).—This is a discussion of the paper by Kunz (*Ceram. Abs.*, **12** [12], 430 (1933)). W.M.C.

Refractory lining for cupolas. L. LONGCHAMBON. *Chim. & ind.*, **30** [5], 1088 (1933); for abstract see *Ceram. Abs.*, **13** [2], 42 (1934). M.V.K.

Cupola linings. J. C. GREEN. Presented at meeting of English Ceramic Society, Nov., 1933, London; *Colliery Guard.*, **147** [3806], 1097 (1933). E.J.V.

Fused refractory blocks. VLADIMIR ŠKOLA. *Chim. & ind.* [Special No.], **29** [6], 825–29 (June, 1933).—Electrothermal methods have an increasing importance in the manufacture of materials which must meet great requirements with regard to chemical and physical resistance. A new method of manufacture in which materials are melted in electric furnaces and cast in molds has been developed in America. An analogous method has been elaborated in Czechoslovakia. The methods of manufacture, chemical and physical properties, experience with melted refractory blocks, and their application in industry are discussed. M.V.K.

BULLETINS AND BOOKS

Notes on spalling tests. F. A. HARVEY. *Amer. Refrac. Inst. Tech. Bull.*, No. 42, 7 pp. (1933).—H. traces the development of the water-dip spalling test, showing wherein it is unfair and unsatisfactory, and the panel spalling test developed at the Mellon Institute, the adoption of which as a standard method has been proposed. A test was made on a panel 18 in. square of fourteen 9-in. straight brick laid with 9 x $2^1/_2$-in. faces exposed and surrounded by a guard ring. This panel was placed against the side of a furnace and preheated 24 hr. with the furnace at 1600°C, then placed twelve times in front of a second furnace, the face of the brick being maintained 10 min. at 1000°C and alternately subjected to a moist air blast for 10 min. The brick were then removed from the panel, the loose pieces detached, and the loss in weight was determined. Data are given to show that the panel test is in close agreement with results obtained in service. W.E.R.

Refractories for use in cupolas. C. E. BALES. *Amer. Refrac. Inst. Tech. Bull.*, No. 43, 7 pp. (1933).—High heat duty fire clays give the best service in cupola blocks; blocks of high initial cost may be cheapest in the long run. Hand-molded block are good in cupolas where small heats are run and pouring is done intermittently, but they are not satisfactory where pouring is continuous. Hand-molded, hand-pressed block are satisfactory where moderate heats are run intermittently. Stiff-mud, machine-pressed block are universally satisfactory. Dry-pressed block give poor service. The service of blocks can be lengthened by suitable operation of the cupola. Extreme cutting in one spot results from excessive oxidation. A high percentage of steel scrap decreases the life and the steel scrap should be used in small pieces. Fluxing material is important, excessive blast should be avoided, and the last charge should not be coked. Slags in malleable cupolas are more corrosive than those in gray iron cupolas. Two satisfactory daubing mixtures are described for use when patching by daubing is economical. W.E.R.

Outline of the manufacture and properties of power-pressed brick. A. C. HUGHES. *Amer. Refrac. Inst. Tech. Bull.*, No. 44, 8 pp. (1933).—A flow diagram for the manufacture of power-pressed refractory brick is given with brief descriptions of the processes and equipment used. A table appended gives the properties of samples of twenty typical power-press (dry-press) brick. W.E.R.

Industrial Heat Transfer. A. SCHACK. Translated by H. Goldschmidt and E. P. Partridge. John Wiley and Sons, New York, 1933. 371 pp. Price $5.00. Reviewed in *Mech. Eng.*, **56** [1], 63 (1934).—This book gives simple formulas, or graphs where simple formulas are not available, dealing with problems of furnaces and heat exchangers. A bibliography is included. See also *Ceram. Abs.*, **9** [3], 240 (1930). F.G.H.

Magnesite. S. MYSCHKIN. Leningrad, 1933. 118 pp., 75 illustrations. Reviewed in *Feuerfest*, **9** [10–11], 153 (1933).—The book deals extensively with (1) raw materials and firing, (2) manufacturing magnesite brick (drying and firing), and (3) different questions on the production and use of caustic magnesite. A detailed description of kilns (including a new one of Ponomarev) for firing magnesite is given. M.V.K.

Handling Heat. NORTON CO. *Power*, **77** [13], 726 (1933).—Boiler furnace refractories are described. F.G.H.

Refractory cements. Useful characteristics and recommendations for their proper use. JOHNS-MANVILLE CO. *Power*, **78** [1], 58 (1934).—Much specific condensed data are included in this practical bulletin. F.G.H.

Shaping refractories. JOHN G. STEIN & CO., LTD. *Refrac. Bull.*, No. 19 (July, 1933); abstracted in *Feuerfest*, **9** [10–11], 154 (1933).—A review of different methods of shaping refractories and their fields of application is given. M.V.K.

PATENTS

Retaining means for furnace wall blocks. E. G. BAILEY AND R. M. HARDGROVE (Fuller Lehigh Co.). U. S. 19,033, Dec. 19, 1933 (reissue).

Furnace wall. P. W. ANTILL (American Arch Co.). U. S. 1,939,646, Dec. 19, 1933. E. G. BAILEY (Fuller Lehigh Co.). U. S. 1,939,650, Dec. 19, 1933.

Refractory brick and process of making. P. H. JUNG (T. N. Kurtz). U. S. 1,942,431, Jan. 9, 1934. The new and improved process of making fire brick comprises calcining at high temperatures raw material having high alumina and low silica contents, bonding the calcined product with a mineral material of colloidal character sub-

stantially free from or low in silica content, molding the final mixture to the desired form, and drying and firing the molded article.

Anchor for refractory furnace linings. J. H. ROYALL (A. P. Green Fire Brick Co.). U. S. 1,941,492, Jan. 2, 1934.

Refractory material and batch and method of making. F. H. RIDDLE (Champion Spark Plug Co.). U. S. 1,942,879, Jan. 9, 1934. A batch for a ceramic material comprises andalusite and finely divided sintered alumina.

Refractory and method of manufacture. K. M. SIMPSON (International Chromium Process Corp.). U. S. 1,943,263, Jan. 9, 1934. A process for producing refractories from fire clay and chrome ore comprises pressing the major portion of the clay into brick, mixing a small amount of the clay with the chrome ore and water, covering the brick with the resultant mixture, and drying and firing the brick.

Method of making composite refractory articles. R. HADDAN (Corning Glass Works). Brit. 402,160, Dec. 6, 1933.

Treatment of aluminous materials. W. B. LLEWELLYN AND P. SPENCE & SONS., LTD. Brit. 402,410, Dec. 13, 1933.

Production of mullite. GENERAL CERAMICS CO. Brit. 402,588, Dec. 13, 1933.

Terra Cotta

Wear resistance of natural stone flooring. D. W. KESSLER. Bur. Stand. *Jour. Research*, **11** [5], 635–48 (1933); R. P. 612.—An apparatus for testing hardness was designed. A comparison made with twenty-two materials which had been on stair treads under service conditions showed the degree of correlation between the tests and actual wear to be high. Marbles, limestones, slates, etc., commonly used in floor surfaces were tested. The approximate values ranged as follows: marbles from 7 to 42; sandstones, 2 to 26; limestones, 2 to 24; slates, 6 to 12; granites, 44 to 66; serpentines, 15 to 111; travertines, 5 to 17. On this scale the most resistant material (quartz) showed a value of 180. Materials used for general flooring purposes in this country show values between 15 and 20. R.A.H.

Scientific and practical study of principal products for floorings in dwellings. IX. F. CHALAMEL. *Rev. mat. constr. trav. pub.*, No. 289, pp. 189–91 *B* (1933).—The respective values of the products used for flooring are discussed. For Part VIII see *Ceram. Abs.*, **13** [2], 43 (1934). M.V.K.

Faulty stoneware mixes and glazes. JACOB KLUG. *Sprechsaal*, **66** [40], 675–78; [41], 693–96 (1933).—Analyses of raw materials have a practical value only when they are made on materials in the same state as those introduced into the mix. The mix must always be composed in such a way that the proportion of bases to acids remains within the limits $B:S = 1:(1–2)$. The best mixes are obtained when the proportion $B:S$ lies near the values of 1:(1.3–1.8). When the ratio oversteps 1:2, difficulties appear. For lime stoneware mixes, the fluxes consist chiefly of CaO, while there is a small amount of $K_2O \cdot Na_2O$ and FeO. For feldspar stoneware, $K_2O \cdot Na_2O$ is the chief flux. As to the appearance and properties of the mix, the composition of the flux molecules is not as decisive as the behavior of the clay substance on firing whether it has the character of kaolin or tends to become dense when fired. Mixes in which the clay substance has a plastic clay origin produce bodies with greater mechanical strength than those in which the clay substance is formed from kaolin or clays containing kaolin. The color of firing is chiefly affected by the proportion of iron oxide to alumina. The grinding fineness of quartz is of the greatest importance in the behavior of the body and its glaze, since a good adherence of the glaze to the body depends on constant coefficients of expansion; the coefficient of expansion increases with increasing fineness and decreases with decreasing fineness. The firing temperature has the same effect on the coefficient of expansion of the mix. The firing temperature of glazes, their composition, and the effect of additions to the mill are discussed in detail. M.V.K.

New chemical stoneware. U. S. STONEWARE CO. *Platers' Guide*, **29** [7], 26 (1933); for abstract see *Ceram. Abs.*, **13** [1], 16 (1934). E.J.V.

British chemical stoneware. G. N. HODSON. *Pottery Gaz.*, **59** [679], 65–70 (1934).—Stoneware is a complex aluminosilicate which usually contains an excess of silica and is therefore definitely acid in character. Stoneware is formed when a clay body partially melts during firing; consequently, the pores which are present in "earthenware" are filled up with molten silicates. A good chemical stoneware will have a porosity lower than 2%; the best stoneware closely approaches porcelain with a porosity in the region of 0.1 to 0.3%. A stoneware is not dependent upon its glaze for acid resistance, but an earthenware is. A description of the manufacturing processes, glazing processes, firing, and physical properties is given. Technical control has improved the quality of the ware considerably. With the exception of strong solutions of hydrofluoric acid, industrial acids have no effect upon stoneware. The proper precautions to prevent breakage in heating materials in stoneware are enumerated. A list of stoneware products, such as pipes, spigots, etc., and their uses is given. E.J.V.

Swelling of lime and its meaning for the building industry. WALTER DAWIHL. *Angew. Chem.*, **46** [27], 461–64 (1933); for abstract see *Ceram. Abs.*, **13** [1], 4 (1934). L.T.B.

Process of plating ceramics with metal. H. W. EDWARDS. *Ceram. Ind.*, **22** [1], 9 (1934).—The new process of evaporating the metal onto the ware in the presence of a high vacuum requires less than half an hour and is comparatively inexpensive. E.J.V.

Equipment and operation of a plant manufacturing Dutch tile stoves. C. KABUS. *Tonind.-Ztg.*, **57** [86], 1012–13; [88], 1036–38 (1933).—This is a description of a modern plant similar in operation to a terra cotta plant. Illustrated. W.M.C.

Efficiency of a roofing tile plant. H. DENDL. *Tonind.-*

Ztg., **57** [86], 1013–14 (1933).—Costs of operating the plant are calculated. W.M.C.

U. S. architecture is developing stream-line design. J. Burn Helme. *Brick Clay Rec.*, **83** [6], 196 (1933); see *Ceram. Abs.*, **12** [12], 426 (1933). E.J.V.

Brick walls from the days of Genghis Khan. Alexis A. Zakharoff. *Bldg. Econ.*, **7** [11], 6–20 (1931).—A description of the old brickwork found in Turkestan, Merv, and Samarkand is presented. The use of brick, gypsum for plastering and as mortar, the complicated system of vaulting, and the development of ceramic materials as enamels and glazes can be observed and studied in these oriental buildings. Illustrated. E.J.V.

PATENTS

Method of preparing and setting tile, etc. Alexander Hopkins and George Thompson. U. S. 1,939,815, Dec. 19, 1933.

Method of making tile. C. B. Lansing and R. H. Louden (National Tile Co.). U. S. 1,941,403, Dec. 26, 1933. The process of making glazed tile comprises filling or partially filling a mold with body material, applying glaze material in sheet form to the body material, compressing the combined materials, removing the tile from the mold, and firing the tile.

Tile setting machine. C. B. Lansing (National Tile Co.). U. S. 1,941,404, Dec. 26, 1933.

Roofing tile. E. Hurden, A. P. Hurden, and S. E. Beeson. Brit. 402,215, Dec. 6, 1933.

Treatment of the surfaces of brick, building blocks, etc. J. A. Johnson and Norbiton Potteries & Brickworks, Ltd. Brit. 402,918, Dec. 20, 1933.

White Wares

Study of the mineralogical and physical characteristics of two lithia-zirconia bodies. Helen Blair Barlett and R. R. Thomas, Jr. *Jour. Amer. Ceram. Soc.*, **17** [2], 17–20 (1934).

Classification of porcelains. A. Granger. *Chim. & ind.* [Special No.], **29** [6], 853–54 (June, 1933).—G. points out the little precision presented by the old classification of porcelain according to Brongniart. The following classification according to the nature of the fusible materials and, if necessary, of the glaze is suggested: (1) feldspathic porcelain with feldspathic glaze, (2) feldspathic calcareous porcelain with feldspathic glaze, (3) feldspathic porcelain with feldspar calcareous glaze, (4) feldspathic calcareous porcelain with lead glaze, (5) magnesia porcelain with lead glaze, (6) fritted porcelain with lead glaze, and (7) phosphorous porcelain with lead glaze. M.V.K.

Semiporcelain tableware. V. P. Zubchaninov and Z. I. Glushanok. *Keram. i Steklo*, **9** [8], 9–12 (1933).—A series of experiments with a semiporcelain which represents an intermediate form between porcelain and faience is described. Tests of articles made from this material showed the high quality of semiporcelain. The composition of the mix for a firing temperature of Seger cone ±1.0, a vitrified body (porosity about zero), and a mechanical strength of 600 kg./sq. cm. has been developed. The mix is easily molded, its plasticity is similar to that of faience, and it undergoes no deformation. A method for applying glazes on the vitrified body and lead and leadless glazes for Seger cones 2 or 3 were developed. M.V.K.

Effects of particle size of flint and feldspar in whiteware. R. F. Geller, D. N. Evans, and A. S. Creamer. *Ceram. Ind.*, **22** [1], 26 (1934); for abstract see *Ceram. Abs.*, **12** [12], 427 (1933). E.J.V.

Glazes in ceramics. Gustav Keppeler. *Ber. deut. keram. Ges.*, **14** [8], 327–43 (1933).—Information is given on the action of glazes under strain, glazes which fit their body properly, various types of glazes on different bodies, etc. E.J.V.

High-frequency properties of dielectrics. I. Anomalous variation of capacity and resistance of quartz with temperature and frequency. K. Nakamura. *Sci. Repts Tôhoku Imp. Univ.*, **22** [3], 614–31 (1933). W.M.C.

Progress report on the manufacture of high frequency insulating materials. L. Rohde. *Z. tech. Physik*, **14** [11], 480–83 (1933).—The manufacture of new products and their properties are described in detail. These materials are used on a large scale for radio tubes and coils. W.M.C.

Three-million volt testing laboratory. Compagnie Generale d'Électro-Céramique. *Nature*, **132** [3341], 744 (1933).—The testing laboratory erected at Ivry near Paris to test porcelain insulators can produce electric discharges up to three million volts. Laboratory and equipment are described. J.L.G.

Refractory production. George Bray & Co. *Elec. Rev.*, **113** [2925], 839 (1933).—Bray & Co. of Leeds, England, makes refractory tubes varying from a diameter of 0.012 in. with 0.004-in. holes through their $1^1/_4$-in. length to a diameter of 4 in. Illustrated. J.L.G.

Josiah Spode's times and triumphs. John Thomas. *Trans. Ceram. Soc.* [Eng.], **32** [11], 489–512 (1933).—T. presents the bicentennial lecture on Josiah Spode and his chief contemporaries, describing his application of artificial power to the pottery industry and the production, transportation, and marketing of spode ware. See also *Ceram. Abs.*, **13** [2], 29 (1934). R.H.H.P., Jr.

PATENTS

Means for suspending porcelain insulators. P. W. Buxton (Wheeler Reflector Co.). U. S. 1,939,760, Dec. 19, 1933.

Method of assembling spark plugs. Hector Rabezzana (A C Spark Plug Co.). U. S. 1,940,323, Dec. 19, 1933.

Manufacture of spark plugs. Hector Rabezzana (A C Spark Plug Co.). U. S. 1,940,324, Dec. 19, 1933.

Shielded spark plug. Hector Rabezzana (A C Spark Plug Co.). U. S. 1,940,325, Dec. 19, 1933.

Pothead or terminal for electric cables. F. H. Meyer and G. E. Moffitt (Okonite-Callender Cable Co., Inc.). U. S. 1,941,614, Jan. 2, 1934.

Insulator. W. A. HILLEBRAND (Ohio Brass Co.). U. S. 1,941,749, Jan. 2, 1934.

Electric insulator. EDMUND BURKE (Brown Co.). U. S. 1,942,133, Jan. 2, 1934. G. H. HALTON (Steatite and Porcelain Products, Ltd.). U. S. 1,942,284, Jan. 2, 1934.

Equipment and Apparatus

Thermocouple potentiometer. A. EGERTON AND A. R. UBBELOHDE. *Jour. Sci. Instruments*, **10** [10], 310–11 (1933).—An instrument giving rapid readings of temperature with a sensitivity of about $^1/_4$ of a degree in the region from −100 to +1200°C is described. The method opposes the e.m.f. of the thermocouple by one nearly equal, thus enabling the millivoltmeter to be read directly in ranges of 100° between −100 and +1200°C, *i.e.*, the voltmeter has full-scale deflection for a difference of 100°C between the junctions of the measuring couple. In this way the sensitivity of a mercury thermometer is gained over wide ranges of temperature. The circuit of the thermocouple potentiometer is given in the paper. J.L.G.

Comparator for the colorimetric determination of p_H values. TINTOMETER, LTD. *Jour. Sci. Instruments*, **10** [9], 292–93 (1933).—Illustrated. J.L.G.

Resistance thermometers for the measurement of relative humidity or small temperature differences. D. C. ROSE. *Can. Jour. Research*, **5** [2], 156–61 (1931). E.J.V.

Thermometer with a "red-shining" mercury. CHEMISCHES LABORATORIUM FÜR TONINDUSTRIE. *Keram. Rund.*, **41** [20], 256 (1933).—A description of a new "thermometer-capillary pipe" is given. Illustrated. M.V.K.

Spectroscopy in the service of industry. J. T. RANDALL. *Nature*, **132** [3336], 574 (1933).—The growing use of spectroscopy in industrial research laboratories for identifying the form and nature of impurities in raw materials and finished parts is considered. J.L.G.

Improved photoelectric recorder. C. W. LA PIERRE. *Gen. Elec. Rev.*, **36** [6], 271–74 (1933); for abstract see *Ceram. Abs.*, **12** [3], 118 (1933). R.H.H.P., JR.

Griffin-Sutton combustion bomb for fuels. T. CARLTON SUTTON. *Jour. Sci. Instruments*, **10** [9], 286–88 (1933).—A combustion bomb which is accurate to 0.1% on calorific value and to 0.05 and 0.1%, respectively, on carbon and sulfur contents is described. Illustrated. J.L.G.

Speedy methods of determining moisture in a substance. S. STANWORTH. *Trans. Ceram. Soc.* [Eng.], **32** [9], 443–54 (1933).—Calcium carbide is mixed in a closed container with a weighed amount of the moist material to be tested, and the percentage moisture content is determined from the rise in pressure caused by the generation of acetylene gas. A second type of tester permits the gas generated to escape and the moisture content is calculated from the loss in weight thus effected. See also *Ceram. Abs.*, **12** [7], 270 (1933). R.H.H.P., JR.

Small portable arc furnace. R. B. BISHOP. *Popular Sci. Monthly*, **124** [1], 61 (1934).—The design and construction of a small test furnace is described and illustrated. F.G.H.

Low cost and high quality in electric furnaces. ANON. *Metal Progress*, **23** [5], 34–37 (1933).—The accuracy of temperature regulation, uniformity of temperature distribution, control of furnace atmosphere, and duplication of heating and cooling rates tend toward high quality and low cost in industrial electric heating. R.H.H.P., JR.

Construction and operation of a coreless vacuum induction furnace. W. BOTTENBERG. *Arch. Eisenhüttenwesen*, **7**, 233–36 (1933).—A new type of vacuum induction furnace is described in which the coil is placed in the vacuum chamber. This furnace has been satisfactory over a long period as shown by the results presented. W.M.C.

High efficiency of a revolving furnace, its calculation, and suggestions for further applications of this furnace system. J. LAMORT. *Feuerfest*, **9** [10–11], 137–40 (1933).—Two kinds of heat transfer (direct and indirect) appearing in a revolving furnace were investigated. The efficiency of enamel and cement revolving furnaces is compared to that of Siemens-Martin and glassmelting furnaces. M.V.K.

Characteristics of fuel-fired furnace control systems. R. A. SMART. *Metals & Alloys*, **4** [10], 153–58 (1933).—The development of a number of furnace control systems, manual, two-position, multiple-position, balancing, and floating controls, together with the design of the attached valves is discussed in relation to temperature regulation, atmospheric control, and fuel economy. Illustrated. R.H.H.P., JR.

Heat-resisting chromium-nickel-iron alloys for furnace construction. I. Load-carrying ability. L. J. STANBERY. *Metals & Alloys*, **4** [9], 127–35 (1933).—S. divides the alloys of the Ni–Cr–Fe series into five general classes and presents curves (representing permissible deformation on the basis of 1% creep in 10,000 hr.) that have been found useful in the design of heat-resisting furnace equipment. A review of the published information on the load-carrying abilities of the alloys from 1200 to 2100°F is compiled in tables and graphs. The design problem is difficult because of the scarcity of high-temperature creep data available to the engineer. Norton's relation, creep rate varies as the $(\text{stress})^5$, is often useful when adequate data are lacking. Illustrated. **II. Selection of alloys for specific conditions of use.** *Ibid.*, **4** [10], 159–64 (1933).—The task of selecting alloys for specific conditions of use is not merely the balancing of the load-carrying ability against the cost but includes a consideration of the nature of the alloy in regard to its resistance to furnace atmospheric conditions, workability, and castability. The properties and industrial applicability of the five classes of heat-resisting alloys are taken up in detail. Illustrated. R.H.H.P., JR.

Metallographic grinding with paraffin impregnated with abrasives. R. L. DOWDELL AND M. J. WAHLL. *Metals & Alloys*, **4** [11], 181–82 (1933).—The preparation of paraffin grinding wheels impregnated with abrasives and the technique of grinding are presented. An inexpensive automatic polishing apparatus is described. Illustrated. R.H.H.P., JR.

Design of forming or extruding dies for clayworking. L. J. SYKES. *Trans. Ceram. Soc.* [Eng.], **32** [8], 371–80 (1933); for abstract see *Ceram. Abs.*, **12** [1], 27 (1933). R.H.H.P., JR.

Construction of mouthpieces. ANON. *Brit. Clayworker*, **42** [500], 257–58 (1933).—The most suitable material for such dies is discussed. R.A.H.

Modern drying and mixing machines for the chemical industries. MASCHINENBAUANSTALT VENULETH & ELLENBERGER A.-G. *Eng. Progress*, **14** [10], 193–94 (1933).—The drying and mixing machines built by M. V. & E. of Darmstadt, Germany, are described. One- and two-cylinder driers consist of revolving steam-heated iron or brass cylinders on which the mass to be dried is applied in a thin layer and scraped off after less than one revolution. The single cylinder drier is coated by dipping in the material to be dried or by an auxiliary roller. Illustrated. J.L.G.

Artificial drying. III. G. BARBEROT. *Rev. mat. constr. trav. pub.*, No. 289, pp. 181–86 *B* (1933).—B. deals in detail with (1) tunnel driers, (2) chamber driers, (3) longitudinal, vertical, and transverse circulation of air, (4) combination of the three systems, (5) distribution of air in the drier's chambers, (6) graphical determination of the operation of a drier, and (7) automatic control of drying. For Part II see *Ceram. Abs.*, **12** [12], 435 (1933). M.V.K.

A conveyer with no moving parts. ANON. *Glass*, **10** [12], 510 (1933).—A new type of conveyer is a cylindrical pipe through which the material is carried by the vibration of the pipe at high frequency. Illustrated. A.J.M.

New mechanical disintegrator. E. W. SCHULTZ AND F. D. BANHAM. *Amer. Jour. Pub. Health*, **20** [7], 771–72 (1930).—A detailed description is given of a mechanically operated disintegrator suitable for grinding most substances commonly disintegrated laboriously by means of a mortar and pestle. Illustrated. E.J.V.

Mechanical casting machine saves labor. ANON. *Ceram. Ind.*, **22** [1], 25 (1934).—The Gem Clay Forming Co., Sebring, Ohio, has built a casting machine which permits two men to do the work of six or seven casting by conventional methods. The machine consists essentially of twelve mold racks on an endless chain conveyer, each rack having a double row of molds, bottom to bottom. The molds are filled at one end and emptied at the other, the entire process being continuous. When the filled rack has advanced to the center of the machine it is automatically turned over and the excess slip runs into a trough emptying into a tank at the side; from here the slip is pumped back into the slip tank. The complete cycle of operation requires from 35 to 40 min. Hydraulic power is employed for the operation. Illustrated. E.J.V.

Trench excavator. FRIED. KRUPP A.-G. *Eng. Progress*, **14** [10], 200 (1933).—An excavator for handling the large amounts of earth removed in digging trenches for cables, gas lines, etc., is described. Illustrated. J.L.G.

Efficiencies of painters' respirators filtering lead paint, benzol, and vitreous enamel sprays. S. H. KATZ, E. G. MEITER, AND F. H. GIBSON. *Amer. Jour. Pub. Health*, **20** [2], 209–10 (1930).—Respirators with cotton, paper, or fabric filters remove 90% or more of lead from air containing paint mist. With silica dust sprays they are less efficient, though most of those tested were more than 50% efficient. E.J.V.

Heat-resisting metals and their use in the ceramic industry. J. FERDINAND KAYSER. *Trans. Ceram. Soc.* [Eng.], **32** [8], 381–401 (1933); see *Ceram. Abs.*, **12** [4], 143 (1933). R.H.H.P., JR.

BOOK

Apparatus for Measuring and Regulating Temperature (Temperatur-Mess- und -Regelgeräte). ALFRED GRÜNWALD. Published by Siemens & Halske, Werner werk, Berlin-Siemensstadt. Reviewed in *Feuerungstechnik*, **21** [11], 156 (1933).—This booklet is a clear review of the subject of temperature supervision and of new apparatus developed to suit the many-sided requirements for measuring, supervising, and regulating the highest temperature and the smallest fluctuations of heat. M.V.K.

PATENTS

Method and apparatus for manufacturing ceramic bodies. A. MALINOVSZKY (Malinite Products, Inc.). U. S. 1,940,554, Dec. 19, 1933. An apparatus for drying, maturing, and glazing ceramic bodies in a continuous manner is described.

Apparatus for producing mineral wool. G. D. SHAVER (Therminsul Corp. of America). U. S. 1,940,975, Dec. 26, 1933.

Apparatus for manufacturing earthenware. D. B. HOWELL. U. S. 1,941,802, Jan. 2, 1934.

Viscosimeter. C. E. FAWKES (De Vilbiss Co.). U. S. 1,942,920, Jan. 9, 1934.

Remote temperature indicator. C. A. DE GIERS (R. C. Murphy). U. S. 1,943,267, Jan. 9, 1934.

Kilns, Furnaces, Fuels, and Combustion

Damp ring kilns. F. SIEKMANN. *Tonind.-Ztg.*, **57** [89], 1050 (1933).—Means are discussed for overcoming difficulties resulting from dampness in the ring kiln. Illustrated. W.M.C.

Fans for water-smoking in ring kilns. P. THOR. *Tonind.-Ztg.*, **57** [85], 1002–1004 (1933). W.M.C.

Mechanical stokers used in kilns. ANON. *Tonind.-Ztg.*, **57** [92], 1088 (1933).—Suspended tracks or small cars of various forms are recommended for carrying coal. Illustrated. W.M.C.

Simultaneous firing of common brick and hollow tile in the ring kiln. ANON. *Tonind.-Ztg.*, **57** [92], 1084–85 (1933). W.M.C.

Electric-arc and arc-resistance furnaces. AXEL WEJNARTH. *Trans. Electrochem. Soc.*, **63**, Preprint No. 34, 355–89 (1933).—The various factors which, under different conditions, may affect the power factor of the electric-arc or the arc-resistance furnace are discussed. The exactness of Lindström's formulas for calculating power factors is demonstrated by practical examples. R.H.H.P., JR.

Rational firing in revolving furnaces. CARL KJELDSEN. *Tonind.-Ztg.*, **57** [91], 1077–78 (1933).—A detailed dis-

cussion of the firing process in revolving furnaces and of attempts to improve it is given. M.V.K.

Determination of maximum current carrying capacity of furnace electrodes. BRUCE L. BAILEY AND RAYMOND R. RIDGWAY. *Trans. Electrochem. Soc.*, **63**, Preprint No. 16, 147–62 (1933).—The permissible maximum current ratings for carbon and graphite furnace electrodes from 7 to 12 in. in diameter were determined at constant ambient temperature. The results show that the highest alternating current resistance in an electrode is at the joints. High power losses may also exist at the contact surface of the electrode clamps. R.H.H.P.,JR.

Coke-oven technology during the year 1932. G. E. FOXWELL. *Fuel Econ. Rev.*, **12**, 9–12 (1933).—A review of technical and economic problems that confront the coke-making industry, which is shown to be in a relatively unfavorable condition in England, is given. W.E.R.

Scientific principles in fuel economy in the glass industry. II. DAVID BROWNLIE. *Glass*, **10** [9], 364–67 (1933).—B. discusses the manufacture, average composition, and heat value of producer gas, water gas, and rich town's gas. Tables are included comparing the above gases made from different materials. **III.** *Ibid.*, **10** [10], 408–10 (1932).—The importance of low-grade town's gas is discussed. B. points out that the low-grade gases can be produced more cheaply and that they are just as efficient industrially as the expensive rich gases. **IV.** *Ibid.*, **10** [11], 452–55 (1933).—Combined low-temperature carbonization and partial gasification of coal are treated. The basic principles are described and three processes are outlined, (1) Maclaurin, (2) Midland Coal Products, and (3) Bussey. Illustrated. **V.** *Ibid.*, **10** [12], 503–509 (1933).—B. describes combined low-temperature carbonization and total gasification of coal. Several English and German processes are described. Tables showing composition and heating values of various types of these gases are given as well as line drawings of some producers. For Part I see *Ceram. Abs.*, **12** [10–11], 393 (1933). A.J.M.

Rôle of water conditions in the formation and differentiation of common (banded) coals. DAVID WHITE. *Econ. Geol.*, **28** [6], 556–70 (1933).—W. explains how, in a normal banded coal bed, the laminae, the proportions of organic components, and the type of coal depend upon the water of the peat-forming area and its changes. J.L.G.

Industrial use of coke-oven gas. A. LEMONNIER. *Chaleur & ind.*, **14** [159], 313–18 (1933).—After having discussed some properties (constants, pressure of distribution, and thermal power) of coke-oven gas, L. describes its use in the metallurgical, glass, and ceramic industries. M.V.K.

Measurement of the viscosity of gases over a large temperature range. B. P. SUTHERLAND AND O. MAASS. *Can. Jour. Research*, **6** [4], 428–43 (1932). E.J.V.

Reducing the fuel bill. ANON. *Power*, **77** [13], 674–75 (1933).—The selection, buying, and efficient burning of coal are described and illustrated. F.G.H.

Fundamentals of combustion space requirements in high-temperature gas furnaces. Report of Committee on Industrial Gas Research, American Gas Assn. Testing Lab., Cleveland, Ohio. *Can. Chem. Met.*, **17** [12], 39 (1933). E.J.V.

Elimination of noise in industrial gas burners. Report of Committee on Industrial Gas Research, American Gas Assn. Testing Lab., Cleveland, Ohio. *Can. Chem. Met.*, **17** [12], 39 (1933). E.J.V.

Mechanically operated gas generator, its origin, and development. GOTTFRIED REITBÖCK. *Feuerungstechnik*, **21** [11], 148–52 (1933).—The origin and development of gas generators according to patent literature is discussed. M.V.K.

Convection and heat transfer. I. M. JAKOB. *Physik*, **1** [4], 153–62 (1933).—This is a review of recent work on the convection and transfer of heat, both with and without change of the state of aggregation. Free and conducted convection are discussed. The theory is given for evaporation and vaporization. The heat transfer during condensation is calculated. The application of heating and cooling data is shown for industrial kilns, steam engines, etc. W.M.C.

Upper pressure limit of ignition. N. N. SEMENOFF. *Nature*, **132** [3336], 566–67 (1933).—The existence of the upper pressure limit of ignition in gases is due to ternary collisions. These are explained by S. on the basis of chain reactions. J.L.G.

Difficulties in firing heavy clay products and their elimination. ANON. *Tonind.-Ztg.*, **57** [90], 1062–63 (1933).—The following faults are discussed: discoloration of the products, cracks developed during drying and firing, deformation, non-uniformity of color in fired products, blistering, and cracking during the cooling period. Instruments used in controlling the firing of the products are described. W.M.C.

Stoneware firing. JACOB KLUG. *Keram. Rund.*, **41** [25], 322–24; [27], 351–52 (1933).—A detailed discussion of the oxidizing and reducing firing for stoneware is given. See also *Ceram. Abs.*, **12** [12], 427 (1933). M.V.K.

BOOK AND BULLETINS

The Tunnel Kiln. FELIX SINGER. 72 pp. Published by the Chemical Laboratory for the Clay Industry, Berlin N. W. 21. Reviewed in *Brit. Clayworker*, **42** [499], 246 (1933).—The work is divided into five chapters: (1) the object and scope of tunnel kilns, (2) a history of such kilns, (3) important details of lay-out, construction, and use, (4) gas producers, and (5) limitations of the tunnel kiln. All the known tunnel kiln designs are given with the exception of the Monnier. R.A.H.

Investigations of Fuels and Fuel Testing (1930 and 1931). Can. Dept. of Mines, 1933. 166 pp. *Power*, **77** [6], 321 (1933).—Four researches on solid fuels and five on natural gas and liquid fuels are included in this report. F.G.H.

Method for rating the grindability or pulverizability of coal. C. E. BALTZER AND H. P. HUDSON. Fuel Research Lab., Can. Dept. of Mines, Ottawa, Canada. *Power*, **77** [10], 547 (1933). F.G.H.

Geology

Depth zones in ore deposition. L. C. GRATON. *Econ. Geol.*, **28** [6], 513–55 (1933).—G. considers the effect of depth on ore deposition. Five subdivisions of the hydrothermal depth zones are dealt with. He considers these as in reality intensity zones caused by variation in pressure. J.L.G.

Evaluation of the "rare" elements in rock analysis. V. M. GOLDSCHMIDT, H. HAUPTMANN, AND C. PETERS. *Naturwissenschaften*, **21** [20], 362–65 (1933).—A discussion of the existence of the rare elements in rocks and their significance in the study of the evolution of rocks is presented. L.T.B.

Change of surface and structure of gels and minerals at high temperatures. JAROSLAV SPLICHAL. *Chim. & ind.* [Special No.], **29** [6], 757–81 (June, 1933).—The surface of silica gel does not change up to 500°. At 1000° its surface diminishes to such an extent that it no longer absorbs water or pigments. Minerals or rocks with a siliceous base have a limited water adsorption in accordance with their little developed surface. Cristobalite was obtained when calcining silica gel. Gels of hydrates of aluminium oxide and bauxite adsorb water even after heating to 500 and 1000° because of alumina. The relation between this compound and corundum obtained by calcining the gel is explained. Gels of hydrates of ferric oxide change into hematite at 200°. At higher temperatures, crystallization progresses and the value of adsorption of water diminishes. X-rays show that the ferric minerals examined are solid solutions of goethite and water, and at 250° they show streaks of hematite. An index of literature dealing with the subject is given. M.V.K.

Researches on alkaline metals in minerals. R. BOSSUET. *Compt. rend.*, **196** [19], 1381–83 (1933); abstracted in *Chim. & ind.*, **30** [5], 1046 (1933).—Minerals having potassium as a constituent usually contain rare alkaline metals. These are not found in minerals containing lithium, sodium, or calcium and little or no potassium. Rubidium is found more frequently than caesium. Rare alkaline metals concentrate in potassium feldspars and micas. Minerals of secondary formation such as zeolites, sodium, and "calsodic" silicates do not contain them. See also *Ceram. Abs.*, **12** [3], 127 (1933). M.V.K.

Talc industry. VIB. *Mines, Carrières, Grand Entreprises*, May, 1933; abstracted in *Ind. chimique*, **20** [234], 500 (1933).—European deposits and their mining are described. M.V.K.

Problems of mining at great depths. S. J. TRUSCOTT. *Nature*, **132** [3328], 229–31 (1933).—The principal problems of mining at depths of 6000 to 8000 ft. below the surface are ventilation and support of the walls of tunnels and shafts. The methods by which these objects are accomplished in several of the world's deepest mines are described. J.L.G.

Thunder Mountain mining district, Valley County, Idaho. CLYDE P. ROSS. *Econ. Geol.*, **28** [6], 587–600 (1933).—The principal products of mineralization are gold with associated silver, pyrite, quartz, and clay. A white clay found is composed of two potassic clay minerals which resemble hydromica. One photomicrograph of the white clay is included. J.L.G.

Mineral zoning in the New Jersey-Pennsylvania-Virginia Triassic area. W. H. NEWHOUSE. *Econ. Geol.*, **28** [7], 613–33 (1933).—The general geology of the region, physiographic evidence of the depth of erosion in the Triassic area from N. J. to Va., and the mineralization of the area are considered. The minerals listed are those of copper and iron. J.L.G.

Bentonite in northern Virginia. R. R. ROSENKRANZ. *Jour. Wash. Acad. Sci.*, **23**, 413–19 (1933).—A description is given of the bentonite beds in the basal Martinsburg of northern Va. A correlation with the beds of central Pa. is suggested. J.B.A.

Giobertite deposits in Czechoslovakia and the present state of their mining. FR. ULRICH. *Chim. & ind.* [Special No.], **29** [6], 298–304 (June, 1933).—U. describes in detail giobertite ($MgCO_3$) deposits of Czechoslovakia, their geological position, mineralogical and chemical composition, and the present state of their exploitation. The genesis of giobertite is discussed. M.V.K.

Two nepheline-sodalite syenites from new localities in northern Rhodesia. FRANK DAWSON ADAMS AND FRELEIGH FITZ OSBOURNE. *Can. Jour. Research*, **6** [5], 571–76 (1932).—Two specimens of nepheline-sodalite syenite from northern Rhodesia are petrologically interesting because of the low content of binary oxides and the presence of an aluminous ægirine. The rocks are similar in chemical composition to lavas found at the northern end of Lake Nyassa and probably belong to the same petrographical province. Illustrated. E.J.V.

Magnesite-bearing rocks in the Anglo-Egyptian Sudan. W. H. TYLER AND W. J. REES. Presented at meeting of English Ceramic Society, Nov., 1933, London; *Colliery Guard.*, **147** [3806], 1097 (1933). E.J.V.

Ceramic raw materials of Saxony. A. LAUBENHEIMER AND H. LEHMANN. *Ber. deut. keram. Ges.*, **14** [9], 367–93 (1933).—After a discussion of the geological history of Saxony and the materials remaining as evidences of the several geologic eras, a more specific outline of ceramic raw materials is presented. The kaolin deposits near Kemmliz and Meissen and through a central trough crossing Saxony are described. Next to the porphyritic kaolins in importance are the granitic kaolins found principally around Kamenz and Klix in northeastern Saxony. The occurrence of fluorspar, particularly around Oelnitz, Schonbrünn, and Wiedersberg, is described in regard to geological formation and size of the deposit. Heavy spar or barite of two types, large crystal white lime barite and a fine or medium crystal reddish barite, occurs principally around Freiberg. Similar discussions of deposits of quartz as quartz sand, quartz sandstones, quartzites, and quartz veins, clay deposits near the Elbe River and in the Lausitz, porphyry tuffa, and pitchstone are presented. Analyses of various ceramic materials are included in tabular form. E.J.V.

Biogeographic relations of the orbitoid foraminifera. THOMAS WAYLAND VAUGHAN. *Proc. Nat. Acad. Sci.*, **19** [10], 922–38 (1933).—The known geographic distribution of the orbitoid foraminifera during successive geological epochs can be explained by the transportation of the organisms by ocean currents during the larval stages. J.L.G.

BOOK REVIEW

Thin-Section Mineralogy. AUSTIN F. ROGERS AND PAUL F. KERR. McGraw-Hill Book Co., Inc., 1933. The method of preparing thin sections of rocks and minerals is described and a general discussion of the polarizing microscope is given which includes (1) parts, (2) precautions to be observed in its use, (3) care, (4) magnification, (5) illumination, and (6) adjustment. An interesting and essential summary is given of the properties of light which touches on (1) theories of light, (2) nomenclature of the wave theory, (3) light vector, (4) speed of light, (5) wave motion, and (6) color of light. In connection with refraction, Snell's law, the index of refraction, dispersion, critical angle, total reflection, indices of refraction of anistropic minerals, measurement of indices of refraction by refractometers, index of refraction by the prism method, the determination of index of refraction with the microscope, the immersion method as an auxiliary to thin-section study, and variation in relief are discussed.

The mechanics by which light becomes polarized and the effect on this polarized light caused by its passage through minerals is discussed in detail and the phenomena arising therefrom are described. It is from these phenomena that the determination of the identity of the mineral is made. The effect of minerals on convergent polarized light, including the formation and interpretation of interference figures and the information to be obtained from them regarding the nature and properties of minerals, is given a description which is entirely justified. Other properties such as color, form or aggregation, cleavage, and orientation are discussed.

A summary of the procedure for the identification of minerals in thin section is given and a key to the mineral tables is supplied. A separate section is devoted to the descriptions of individual minerals, and the order in which they are taken up facilitates the identification of a mineral by group elimination.

The manner of description and the selection and number of illustrations have added interest and clarity.

C. H. TURNER

BULLETIN AND BOOKS

Feldspar. H. O. ROGERS AND C. GALIHER. Bur. Mines, *Mineral Resources U. S.*, 1932–33. 8 pp. 5¢ from Supt. of Documents, Washington, D. C. R.A.H.

Physical Geodesy (Physikalische Geodasie). F. HOPFNER. xi + 434 pp. Akad. Verlagsges. m.b.H., Leipzig, 1933. 31M. Reviewed in *Nature*, **132** [3340], 693–94 (1933).—H. discusses the earth's figure from the viewpoint of the mathematical theory of attractions. Actual technical details of measurement are not considered. J.L.G.

Numerical Data of the Crystallography, Mineralogy, and Structure of Matter by X-rays (Donneés numeriques de Cristallographie, Minéralogie, Structure de las Matière par les Rayons X). Edited by P. NIGGLI, E. BRANDENBERGER, AND M. MATHIEU. Gauthier-Villars & Cie., Paris, France. *Mining & Met.*, **15** [325], 70 (1934).—Various facts are presented relating to crystallized substances and their aggregates and results of geometrical, physical, and chemical measurements of crystallographically defined substances or of chemical compounds otherwise sufficiently proved to represent definite mineral species. E.J.V.

Soils, Their Origin, Constitution, and Classification. G. W. ROBINSON. D. Van Nostrand Co., New York, 1932. Reviewed in *Nature*, **132** [3329], 261–62 (1933); for abstract see *Ceram. Abs.*, **12** [2], 79 (1933). J.L.G.

The Mesolithic Age in Britain. J. G. D. CLARKE. xxiii + 223 pp. University Press, London, 1932. 15s net. Reviewed in *Nature*, **132** [3329], 260 (1933).—C. terms the gap between the Paleolithic and Neolithic ages the Mesolithic and surveys the evidence available on this age. J.L.G.

Igneous Rocks and the Depths of the Earth. R. A. DALY. xvi + 598 pp. Reviewed in *Nature*, **132** [3336], 533 (1933); for abstract see *Ceram. Abs.*, **13** [1], 23 (1934). J.L.G.

Descriptive Petrography of the Igneous Rocks. Vol. II. ALBERT JOHANNSEN. xxxi + 428 pp. Reviewed in *Nature*, **132** [3340], 691–92 (1933); for abstract see *Ceram. Abs.*, **12** [10–11], 397 (1933). J.L.G.

Chemistry and Physics

Phase equilibria in the systems TiO_2, TiO_2–SiO_2, and TiO_2–Al_2O_3. E. N. BUNTING. Bur. Stand. *Jour. Research*, **11** [5], 719–25 (1933).—The stable form of TiO_2 above 400°C was found to be rutile with a melting point of 1825°C. It forms no compounds with SiO_2 but gives a eutectic with 89.5% of SiO_2 at 1540°C. With Al_2O_3 a compound $TiO_2 \cdot Al_2O_3$ is formed, melting at 1860°C. This compound forms a eutectic with TiO_2 at 15 wt. per cent Al_2O_3 and 1715°C and a second eutectic with Al_2O_3 at 62 wt. per cent Al_2O_3 and 1850°C. Several low melting fluxes with nonvolatile acid radicals are described. R.A.H.

Notes on the shrinkage of clays during drying. J. W. MELLOR. *Trans. Ceram. Soc.* [Eng.], **32** [10], 455-71 (1933); reprinted in *Bull. Brit. Refrac. Research Assn.*, No. 31 (June, 1933).—Minimum straining in the drying of clays occurs when the two factors, (1) rate of evaporation from the surface of the clays (humidity drying) and (2) speed at which the water diffuses in the interior (internal distribution of water), are nearly equal. The presence of acidulated water, caused by coagulating the colloids, should favor rapid drying of ordinary fire clays. It is shown mathematically that a linear relationship exists between the volume of a drying slab and the proportion of contained water. The properties of a clay are sometimes influenced by the orientation or "set" of the granules during drying. R.H.H.P., JR.

Studies on peptizing agents for clays by means of a photocell. REIZO ISOMATSU. *Repts. Imperial Ceram. Expt. Inst.*, No. 11, pp. 1–12 (1933).—The effectiveness of a few commonly used peptizing agents for clays was studied using a barrier-layer photocell to measure the turbidity of the clay suspensions. From 4 to 10 g. of each clay were made into a thin suspension with 1 liter of water with the

addition of a small amount of a peptizing agent (about 0.001~0.006 mol solution). The suspension was kept in a small transparent vessel and an electric lamp was lighted on one side; the amount of transmitted energy was converted into electricity by means of a barrier-layer photocell and measured by a millivoltmeter. The turbidity of the suspension was determined with this method in course of time. This method gives accurate numerical values and the manipulation is quite simple and quick. Sodium pyrophosphate was found to be far more effective than citrates of soda or potash as a peptizing agent for most clays. Illustrated.

Studies on relations between fineness of particles and plasticity of ceramic bodies. REIZO ISOMATSU. *Repts. Imperial Ceram. Expt. Inst.*, No. 11, pp. 13–41 (1933).—Some Japanese feldspathic clayey materials from northeastern as well as from Kiushu Districts which have been regarded as valuable from the standpoint of immense quantity and favorable chemical compositions are known to possess insufficient plasticity. Improvement of the plastic property of these materials, if possible, seems to be of great economic importance in the ceramic industry in Japan. In order to study the question thoroughly, I. tried to confirm the function of extremely fine particles upon plasticity of body. He selected numerous clays and classified them into four groups in order of degrees of plasticity, which were judged by reliable practical potters; the fineness of each material was carefully determined by means of Andreasen's pipette method and fully examined. From the results, so far as the experiments are concerned, the following conclusions are recognized: (1) Particles of extreme fineness of the order of less than 1μ diameter seem to affect the formability directly; the presence of fine particles of the above order in a body affects the plasticity. (2) The least content of such minute particles for the best working condition is found to be about 20%, and the higher the content, the more plastic the body becomes. (3) Bentonite was found to consist of an exceptionally high percentage of subcolloidal and colloidal particles and was found to give sufficient plasticity to a meager body even when added in a small amount. (4) Acid earths which are rich in content of extremely fine particles were found to be highly plastic, although they were generally understood to possess no plasticity at all, and it is confirmed that they can be used with meager materials to improve plasticity. (5) Bodies which contain no particles of such minute dimensions possess practically no plasticity. The content of subcolloidal plus colloidal particles in a body determined by means of Andreasen's method may be taken as a measure of plasticity of the body. (The writer means by "subcolloids" particles whose diameters lie between 0.1 and 1.0μ.) Illustrated.

X-ray observations of Kanbara clay and fuller's earth. HAJIME ISOBE. *Bull. Inst. Phys. Chem. Research*, **12**, 441 (1933); abstracted in *English Sci. Papers Inst. Phys. Chem. Research*, May, 1933.—Both substances crystallize in the hexagonal system. J.B.A.

Graphical methods for calculating ceramic batches. MAX DONATH. *Ber. deut. keram. Ges.*, **14** [11], 488–92 (1933).—An algebraic method of computing ceramic batches on the basis of rational analyses, considering the bodies to consist of three components, clay substance, quartz, and feldspar, is explained in considerable detail. The construction and application of a nomograph for batch composition calculation is described and discussed at length. E.J.V.

X-ray examination of ceramic raw materials. V. T. NAKAI AND Y. FUKAMI. *Jour. Soc. Chem. Ind.* [Japan], **36** [11], 604–606*B* (1933).—X-ray examinations were made on different kinds of "Mitsuishi-roseki," materials used for the preparation of glazes and pottery, and refractory products. Their chief ingredients are the silicates of magnesium or aluminum; their composition is given. The principal minerals comprising "rosekis" are kaolinite, pyrophyllite, and some diaspore. The changes occurring on heating in the latter two were studied. It was found that pyrophyllite gives off its water of crystallization at 500 to 600°; the crystalline material produced by dehydration remains unchanged up to 1050°; at 1100°, it decomposes suddenly into amorphous silica and alumina. At 1200° a part of the silica and alumina combine again and form mullite; some cristobalite is formed by the surplus silica, which increases in amount on heating to higher temperatures. Diaspore changes its crystalline structure also at 400 to 500°, giving off the water of crystallization. Up to 1200°, the crystalline material obtained remains stable; its diffraction pictures are similar to those of corundum. For Parts III–IV see *Ceram. Abs.*, **13** [2], 47 (1934). M.V.K.

State of combination of iron oxide in ceramic clays. OTTO KRAUSE AND HEINRICH TITZE. *Ber. deut. keram. Ges.*, **14** [11], 493–507 (1933).—To determine the state of combination of iron oxide in clays, five clays with different iron oxide contents and different colors were examined. After X-ray, chemical, and thermal tests resulted in no serviceable explanation, tensieudiometric decomposition experiments and color changes showed the appearance of 2° of dehydration in the temperature range up to 400°. In conformity with tests on natural iron oxide hydrates, the iron oxides of the tested clays must be present in the form of hydrated oxides. From microscopic examinations of the clays it is evident that the different degrees of division of the hydrated iron oxides are the cause of their difference in coloring. The often described parallelism of the increased solubility in hydrochloric acid of iron oxide and alumina on heating is not unconditionally traceable to the constitutional combination of iron oxide in the clay substance. It can much more readily be explained by the hindering of the solubility due to the fine division with the clay particle aggregates; the old assumption of an iron substance analogous to clay substance is proved to be weak. E.J.V.

Industrial applications of the polarographic method. J. HEYROVSKY. *Chim. & ind.* [Special No.], **29** [6], 204–10 (June, 1933).—This method, presenting numerous advantages, may be applied for determining mineral and organic compounds. A number of applications are described. M.V.K.

Application of a polarographic method in determining alkalis, in particular in silicates with a high alumina content. VLADIMIR MAJER. *Chim. & ind.* [Special No.], **29** [6], 211–14 (June, 1933); for abstract see *Ceram. Abs.*, **12** [8], 312 (1933). M.V.K.

Ternary system Na_2SiO_3–$Na_2Si_2O_5$–$NaAlSiO_4$. C. E.

TILLEY. *Mineralog. petrog. Mitt.*, **43** [6], 406–21 (1933); abstracted in *Sprechsaal*, **66** [40], 681 (1933).—The study of this system shows the range of stability of nepheline ($NaAlSiO_4$) and carnegieite ($NaAlSiO_4$) within the soda–alumina–silica system. It is relatively a simple system without combination; four fields emerge in which the primary phases are Na_2SiO_3, $Na_2Si_2O_5$, nepheline, and carnegieite. The ternary eutectic lies at 8.5% sodium metasilicate, 6.35% sodium disilicate, and 28% nepheline; the melting temperature is 760°. The limiting curve which deviates to the ternary eutectic from the binary eutectic between nepheline and disilicate shows a temperature decrease of 8°. Because of the solid solution, the limiting curve between nepheline and carnegieite is not isotherm but proceeds from 1163 to 1248°. In three-component systems glasses with compositions lying near the ternary eutectic show inert crystallization, especially when their primary phase is nepheline or disilicate. The reason for the flat character of the liquid curve of sodium disilicate in the two-component system is the dissociation of the disilicate in the melt ($Na_2Si_2O_5 \rightleftarrows Na_2SiO_3 + SiO_2$); in three-component systems, the same explanation may be used for the character of the liquid surface of the disilicate. M.V.K.

Calculating series of mixtures with given lead silicates. JOSEF WOLF. *Sprechsaal*, **66** [47], 805–807 (1933).—Ways for the production of mixtures composed of given lead silicates are described and illustrated by examples. Tables and diagrams are given. M.V.K.

Properties of tricalcium silicate from basic open-hearth steel slags. OLAF ANDERSEN AND HARLEY C. LEE. *Jour. Wash. Acad. Sci.*, **23**, 338–51 (1933).—Samples of $3CaO \cdot SiO_2$ isolated from open-hearth steel slags have the following properties. The crystals belong to the trigonal system and have a rhombohedral development. The most prominent form is the basal pinacoid $C(0001)$. One or two rhomobohedrons are always present but no other forms are observed. Axial ratio $c:a = 1.7730$. The mean values of the angles are $C(0001):R(1011)$ 63°58′, $c(0001):r(2021)$ 76°15′, $R(1011):R(1101)$ 77°45′. Hardness is between 5 and 6. The crystals are brittle and full of cracks and have an uneven fracture. $d_4^{30} = 3.224$. The streak is light gray, almost white. Thin sections are colorless in transmitted light. Neither pleochroism nor twinning is observed. The refractive indices are as follows where the first figure is the wavelength of light used in Å, the second is ω, and the third ϵ: 5351, 1.733, 1.728; 5893, 1.724, 1.719; 6708, 1.714, 1.709. J.B.A.

Crystal structure of sodium ferrite. S. GOLDSZTAUB. *Compt. rend.*, **196**, 280–82 (1933); abstracted in *Sprechsaal*, **66** [43], 730 (1933).—With a long heating of Fe_2O_3 with Na_2CO_3 to light red heat, crystals of $Na_2O \cdot Fe_2O_3$ are obtained. The ferrite has a rhomobohedric structure and the rhomobohedric axis is $a = 5.59$ Å, $\alpha = 35°20'$. The found density is 4.23 and the calculated, 4.3 (under the assumption that the elementary cell contains 1Fe, 2O, and 1Na). The space group is $D^5R\,3m$. The atomic arrangement in the molecule is discussed. M.V.K.

Crystal structure of borides of the type MeB_6. F LAVES. *Z. phys. Chem.*, **B22** [1–2], 114–16 (1933).—Compounds of this type are considered as three-dimensional lattices in whose interstices the metal atoms are situated. Some X-ray crystal measurements were made on alkaline-earth and rare-earth borides. L.T.B.

X-ray diffraction by volcanic glasses and ashes. M. HIRATA. *Sci. Papers Inst. Phys. Chem. Research*, **18** [370], 237 (1932).—From the changes of these patterns on heating it is concluded that the water contained in the glassy rock is not in its ordinary state but is intimately connected with the molecular arrangement. J.B.A.

Ray-surface, optical indicatrix, and their interrelation: An elementary presentation for petrographers. GEORGE TUNELL. *Jour. Wash. Acad. Sci.*, **23**, 325–38 (1933).—The two fundamental theories of optical petrography are restated in simple geometrical form and their chief applications in petrography are discussed. J.B.A.

Arc spectrum of silicon in the red and infra-red. C. C. KIESS. Bur. Stand. *Jour. Research*, **11** [6], 775–82 (1933); R.P. 624.—No accurate description of the red and infra-red portion of the arc spectrum of silicon has been published in the 40 years that have elapsed since Rowland's work which terminated at 5948A. In this paper wavelengths are given for 130 new lines between 6125 and 11,290 A, many of which are present in the solar spectrum, including the strongest hitherto unidentified Fraunhofer line. More than 50% of these lines have been classified as combinations between new terms and terms already established for SiI. The new terms arise from the electron configurations containing the $4p$, $4f$, and $5f$ electrons. R.A.H.

Recent developments in the field of microphotography with ultra-violet light. A. KOHLER. *Naturwissenschaften*, **21** [8], 165–72 (1933).—K. discusses the theory and some of the recent developments in the field. L.T.B.

Formula for specific volumes of saturated vapors. CYRIL H. MEYERS. Bur. Stand. *Jour. Research*, **11** [5], 691–701 (1933); R.P. 616.—A formula for calculating the specific volume of saturated vapors is given. For pressures up to one-fourth the critical pressure, the formula represents the data on 23 substances within the experimental error. Graphs are given showing the application of the formula to 15 substances. R.A.H.

Collation of experimental data. II. A. ALISON. *Glass*, **10** [9], 371–73 (1933).—Data represented by a straight line and those represented by parabolic or kindred relationships are discussed. The determination of constants by the method of least squares is described. **III.** *Ibid.*, **10** [10], 422–23 (1933).—A. explains the application of a nomograph to a typical equation and describes its construction. **IV.** *Ibid.*, **10** [11], 466–67 (1933).—The expression of a curve by means of a polynomial is treated. For Part I see *Ceram. Abs.*, **12** [10–11], 403 (1933). A.J.M.

Knowledge of the heterogeneous reaction of the type A (solid) + B (gas) $\rightleftarrows$ C (solid). I. Deviation of the equilibrium constant, "apparent equilibrium" and its significance. J. ZADWADSKI AND S. BRETSZNAJDER. *Z. phys. Chem.*, **B22** [1–2], 60–78 (1933).—Deviations of the equilibrium constant for $CaCO_3$, $CdCO_3$, and $CaSO_3(CaS + 3CaSO_4)$ are discussed. The rôle of nucleus formation during the course of reaction is shown, and a further contribution is given to the proof of the Langmuir conception that the seat of the reaction is at the surface of the solid phase. **II. Kinetics of carbonate formation and decomposition.**

Ibid., **B22** [1–2], 79–96 (1933).—The effect of pressure, compound structure, preliminary treatment of the system, and temperature on the speed of formation and decomposition of carbonate was studied. The results of these experiments are in agreement with the theory expressed in Part I. L.T.B.

Potters' materials X-rayed. W. L. BRAGG. Presented at meeting of English Ceramic Society, Dec., 1933; *Pottery Gas.*, **59** [679], 82 (1934). E.J.V.

Rational analysis in sagger manufacture. CARL RANCKE. *Keram. Rund.*, **41** [25], 320–22 (1933).—The calculation of the rational analysis from the chemical analysis is illustrated by examples. M.V.K.

Determining lime content. P. L. *Rev. mat. constr. trav. pub.*, No. 289, pp. 339 (1933).—Lime is precipitated by oxalic acid and ammoniac in an acetic hydrochloric solution. The oxalates of alumina and iron remain in solution. The oxalate of lime is collected, treated with sulfuric acid, and titrated with potassium permanganate. M.V.K.

Behavior of sands at higher temperatures. FRANZ ROLL. *Ber. deut. keram. Ges.*, **14** [11], 484–88 (1933).—Following an investigation of the behavior of sands at temperatures up to 800°C it was found that with increasing temperature the dyestuff adsorption and the settling of sands decrease. A turning point of these properties is determined between 300 and 400°; this turning point lies in close connection with a loss of the chemically combined water (reduction of the hydrate sheath). The solidity of the sands decreases with the increase in temperature. Illustrated. E.J.V.

BOOKS

Fundamentals of Physical Chemistry. E. C. H. DAVIES. *Jour. Amer. Chem. Soc.*, **55** [12], 5064 (1933); see *Ceram. Abs.*, **12** [9], 344 (1933). F.G.H.

Physico-Chemical Methods. JOSEPH REILLY AND WILLIAM NORMAN RAE. 2d ed., revised. xv + 822 pp. Methuen and Co., Ltd., London, 1933. 42s net. Reviewed in *Nature*, **132** [3330], 296–97 (1933).—The book is primarily adapted to the needs of the research worker. Nearly all aspects of experimental physical chemistry are considered. J.L.G.

Quantitative Chemical Analysis. G. M. SMITH. Macmillan Co., New York, 1933. 212 pp. Price $2.25. *Jour. Inst. Metals*, **53** [11], 683 (1933). F.G.H.

Industrial Chemistry. E. R. RIEGEL. Chemical Catalog Co., Inc., New York, 1933. 784 pp. Price $6.00. Reviewed in *Ind. Eng. Chem.*, **25** [12], 1409 (1933); *Jour. Inst. Metals*, **53** [11], 683 (1933). F.G.H.

Potentiometric Analysis (Die Elektrometrische (Potentiometrische) Massanalyse). E. MÜLLER. Theodor Steinkopff, Dresden and Leipzig, 1933. 276 pp. *Jour. Inst. Metals*, **53** [8], 479 (1933). F.G.H.

The System Kieselguhr, Quartz Ware and Quartz Glass, and Silica Block. E. ZSCHIMMER. *Angew. Chem.*, **46** [27], 468 (1933); for abstract see *Ceram. Abs.*, **12** [10–11], 380 (1933). L.T.B.

Colloid Chemistry in Ceramics. HANS KOHL. *Z. phys. Chem.*, **A165** [1–2], 157 (1933); see *Ceram. Abs.*, **11** [5], 333 (1932). L.T.B.

Chapters in Modern Inorganic and Theoretical Chemistry. ERNEST S. HEDGES. vii + 279 pp. Edward Arnold and Co., London. 12s 6d net. Briefly reviewed in *Nature*, **132** [3325], 121 (1933).—The treatment is rather superficial. J.L.G.

Handbook of Chemistry and Physics: Ready-Reference Book of Chemical and Physical Data. 18th ed. 1818 pp. Chemical Rubber Co., Cleveland, Ohio. Price $6.00. *Gas Age-Rec.*, **72** [21], 486 (1933).—New material included in this edition consists of characteristics of thermionic tubes, table of isotopes, organic analytical reagents, p_H values, and solubility charts. Many minor corrections and additions have been made. For 17th ed. see *Ceram. Abs.*, **12** [7], 282 (1933). E.J.V.

Thermostatics (Thermostatica). J. E. VERSCHAFFELT. "De Sikkel," Antwerpen, Belgium, and P. Noordhoff N. V., Groningen, Holland, 1933. 472 pp. Reviewed in *Jour. Amer. Chem. Soc.*, **55** [12], 5065 (1933). F.G.H.

Glass and Ceramic Filters for Laboratory Filtering, Distribution of Gases, Dialysis, and Extraction. P. H. PRAUSNITZ. Reviewed in *Ind. chimique*, **20** [234], 544 (1933); for abstract see *Ceram. Abs.*, **12** [10–11], 404 (1933). M.V.K.

Methods for the quantitative analysis of coal ash. Physical and Chemical Survey of National Coal Resources. *Dept. Sci. Ind. Research Paper*, No. 28. H. M. Stationery Office. 6d. *Nature*, **132** [3339], 681 (1933).—The paper is a collation of tested methods of silicate analysis appropriate to coal-ash determinations. Attention is also directed to special methods of spectrum analysis. J.L.G.

Manufacture of Soda. TE-PANG HOU. Chemical Catalog Co., Inc., New York. 365 pp. Price $8.00. *Can. Chem. Met.*, **17** [11], 35 (1933).—The subject of soda manufacture is treated with special reference to the ammonia process. The book contains two chapters on the manufacture of caustic by chemical and electrolytic methods, giving a complete account of the alkali industry. E.J.V.

Hydrogen-Ion Concentration and Its Practical Applications. F. L. LA MOTTE, W. K. KENNY, AND A. B. REED. *Jour. Inst. Metals*, **53** [10], 599 (1933); see *Ceram. Abs.*, **12** [10–11], 404–405 (1933). F.G.H.

Handbook of Mathematical Tables and Formulas. R. S. BURINGTON. *Power*, **77** [8], 438 (1933); *Jour. Inst. Metals*, **53** [10], 598 (1933); see *Ceram. Abs.*, **12** [10–11], 404 (1933). F.G.H.

PATENTS

Manufacture of zinc oxide. B. N. MCCRAVEN (New Jersey Zinc Co.). U. S. 1,941,569, Jan. 2, 1934.

Treatment of silicates with acids in order to obtain their soluble salts. F. JOURDAN. Brit. 402,977, Dec. 20, 1933.

Iron oxide. VEREIN FÜR CHEM. UND METALLURGISCHE PRODUKTION. Fr. 744,777, April 26, 1933. Red Fe_2O_3 is made, with simultaneous production of Na_2SO_4, by transforming $FeSO_4$, in known manner, into the double salt of $FeSO_4$ and Na_2SO_4, heating the double salt to redness with an amount of Na_2CO_3 corresponding to the content of Fe and with admission of air. The product is separated by washing into a residue of Fe_2O_3 and a solution of Na_2SO_4. The double salt may be dehydrated before adding Na_2CO_3. (*C.A.*)

Silicates. HENKEL & CIE. G.M.B.H. Fr. 744,970, April 29, 1933. Alkali or alkaline earth silicates are made

by treating alkali chlorides and SiO_2, if necessary with the addition of alkaline earth metals as well as other fluxes, by steam at a high temperature, the heat being produced in the interior of the contents of the furnace by electric means, the contents of the furnace acting as resistance. (*C.A.*)

Zinc white. HENRY E. COLEY. Fr. 745,345, May 9, 1933. Zn is vaporized in a rotating chamber, in the presence of a substance having a basis of C in amount sufficient to ensure reducing conditions in the neighborhood of the metal, to prevent the formation of a crust of ZnO and to prevent the formation of a free surface of molten metal inside the chamber. The combustion of the vapors to ZnO is completed in a mobile combustion chamber in rotation. (*C.A.*)

Calcium silicate. RUDOLF ZELLMANN (Chemische Fabrik von Heyden A.-G.). Ger. 570,856, Feb. 22, 1933. Reactive $CaSiO_3$ is prepared by mixing a solution of a readily soluble silicate or polysilicate, such as Na_2SiO_3, with a solution of a readily soluble Ca salt. The conditions are such that the SiO_2 content of the silicate solution is not under 10% and the Ca content of the Ca salt solution is not under 7.5%. (*C.A.*)

Silicates. CARL LUCKOW. Ger. 571,970, March 8, 1933. Heavy metal silicates are prepared by electrolysis. The electrolyte consists of a mixture of 2 aqueous solutions of alkali metal salts, such as $NaClO_3$ and Na_2SiO_3, and the electrodes of a heavy metal such as Pb or Cu. The silicate of the electrode metal is so produced. (*C.A.*)

General

"Land of the spree and home of the crave." EDITORIAL. *Bull. Amer. Ceram. Soc.*, **13** [1], 1–2 (1934).

Curricula for undergraduates. EDITORIAL. *Bull. Amer. Ceram. Soc.*, **13** [1], 2–4 (1934).

Thirty-sixth Annual Meeting, American Ceramic Society. Art Division program titles. F. R. Carder on artistic glass. *Bull. Amer. Ceram. Soc.*, **13** [1], 5 (1934). **R. A. Weaver and H. F. Bopp addresses. Cincinnati Art Museum and University of Cincinnati invite ceramists.** *Ibid.*, p. 6. **Joseph Sinel on design in modern industry. Glass Division additional titles. Rookwood living proof of profit in nonprofiteering industry.** *Ibid.*, p. 7. **Enamel Division Program** (titles and abstracts). *Ibid.*, pp. 8–9. **Refractories Division program** (titles and abstracts). *Ibid.*, pp. 9–13. **Structural Clay Products Division program** (titles and abstracts). *Ibid.*, pp. 13–14. **White Wares Division Program** (titles and abstracts). *Ibid.*, pp. 14–15. **H. M. Kraner and F. R. Henry as reasons for success of Meeting.** *Ibid.*, p. 15. **Program schedule for Meeting.** *Ibid.*, p. 16. **Lectures by A. L. Day and G. W. Morey. The Geophysical Laboratory.** *Ibid.*, pp. 17–20.

Annual Meeting of the Ceramic Association of New Jersey. *Bull. Amer. Ceram. Soc.*, **13** [1], 28 (1934).

A. P. Green honored. *Bull. Amer. Ceram. Soc.*, **13** [1], 28 (1934).

New York Ceramic Studios organized. *Bull. Amer. Ceram. Soc.*, **13** [1], 28 (1934).

Presentation of Chemical Industry Medal to James G. Vail. *Bull. Amer. Ceram. Soc.*, **13** [1], 29 (1934).

Enamel Short Course at the University of Illinois. Midwest Enamelers Symposium. *Bull. Amer. Ceram. Soc.*, **13** [1], 27 (1934).

Tariff ruling on art glass. *Bull. Amer. Ceram. Soc.*, **13** [1], 29 (1934).

Mayor La Guardia on research. *Bull. Amer. Ceram. Soc.*, **13** [1], 30 (1934).

Local Sections of the American Ceramic Society: Pittsburgh Section Meetings. *Bull. Amer. Ceram. Soc.*, **13** [1], 21 (1934).

Necrology: Paul E. Titsworth. *Bull. Amer. Ceram. Soc.*, **13** [1], 25–26 (1934).

How an annual meeting helps ceramists. ROSS C. PURDY. *Better Enameling*, **4** [12], 14 (1934). E.J.V.

Dust hazard in air-pressure abrasive blasting (sand-blasting). LEONARD GREENBURG AND C.-E. A. WINSLOW. *Arch. für Gewerbepath. Gewerbehyg.*, **3** [4], 577–99 (1932); *Amer. Jour. Pub. Health*, **23** [2], 159 (1933).—Positive air-pressure helmets with glass eye-shields and an air supply of 6 cu. ft./min. furnish complete protection for the worker under the worst conditions found in actual operation. E.J.V.

Sand and metallic abrasive blasting as industrial health hazard. J. J. BLOOMFIELD AND LEONARD GREENBURG. *Jour. Ind. Hygiene*, **15**, 184–204 (July, 1933); *Amer. Jour. Pub. Health*, **23** [9], 991 (1933).—A description of the four types of air pressure abrasive blasting equipment in general use is presented. E.J.V.

Efficient dust mask. CHICAGO EYE SHIELD CO. *Ind. Finishing*, **9** [11], 23 (1933).—A new dust mask designed primarily for sand- and shot-blasting workers is described. Illustrated. J.L.G.

Observations and studies on silicosis by diatomaceous silica. ROBERT T. LEGGE AND ESTHER ROSENCRANTZ. *Amer. Jour. Pub. Health*, **22** [10], 1055–60 (1932). E.J.V.

Auxiliary equipment in brick plants. A. GALLASCH. *Tonind.-Ztg.*, **57** [87], 1026–27 (1933).—Equipment is described for measuring the draft of kilns and the firing behavior of common brick. The porosity of roofing tile should be tested both for air and water as well as the freezing resistance of common brick. W.M.C.

Porosity. C. R. F. THRELFALL. Presented at meeting of English Ceramic Society, Nov., 1933, London; *Colliery Guard.*, **147** [3806], 1096 (1933). E.J.V.

Method for removing iron from ceramic raw materials. R. STAUFER AND K. KONOPICKY. *Keram. Rund.*, **41** [25], 324–25 (1933); for abstract see *Ceram. Abs.*, **12** [5], 206 (1933). M.V.K.

Steam boilers in pottery works. JOHN PHILLIPS. *Trans. Ceram. Soc.* [Eng.], **32** [10], 479–87 (1933).—Fuel economy in the production of power is stressed. Some of the contributory causes to low efficiency in operation are (1) loss by imperfect combustion, (2) poor heat transfer, (3) waste of unburned fuel through the grate, and (4) excess air passing through the furnace. Solutions of the problems are discussed. See also *Ceram. Abs.*, **12** [6], 246 (1933). R.H.H.P., JR.

Depth of 130 ft. excavated in one cut. R. WENZEL.

Eng. Progress, **14** [10], 196 (1933).—W. describes a bucket-chain excavator in use in the Friedrich Ernst colliery near Senftenberg, Germany, which is capable of excavating to a depth of 130 ft. at one cut when the adjustable bucket ladder (180 ft. long) rests at an angle of 45°. With every fourth link of the bucket chain carrying a 0.97-cu. yd. bucket it has a theoretical output of 1160 cu. yd./hr. The actual output for one month was 1300 cu. yd./hr. of operation. The bucket motor develops 665 h.p. The excavator is carried on 56 wheels which run on a 3-rail track. Two trains placed simultaneously under the hopper of the excavator can have their cars loaded alternately by opening and shutting gates in the hopper. Illustrated. J.L.G.

Mining and transport of raw materials used in the ceramic industries: a discussion. FRANK WEST, E. GWYNNE VEVERS, W. BOYD MITCHELL, AARON JOHNSON, AND ALFRED DAVIES. *Trans. Ceram. Soc.* [Eng.], **32** [9], 415–42 (1933).—The discussion includes a description of the general mining practices and the conditions in the clay industry. The importance of evaluating the true cost of the raw material to the brickmakers is stressed. Illustrated. R.H.H.P., JR.

The electric furnace and its products in the U.S.S.R. C. H. VOM BAUR. *Trans. Electrochem. Soc.*, **63**, Preprint No. 35, pp. 391–94 (1933).—By the end of 1934, 449 electric melting and smelting furnaces for the production of steel, iron, nonferrous alloys, ferro-alloys, silicon carbide, and barium aluminate will be in operation in Soviet Russia. R.H.H.P., JR.

Production needs govern choice of drive. ROBERT W. DRAKE. *Factory Management & Maintenance*, **91** [12], 501–503 (1933).—D. discusses the ways in which production considerations govern the deciding factors in choosing between individual and group drives. Illustrated. J.L.G.

Help in choosing a.-c. motors. A. A. MERRILL. *Factory Management & Maintenance*, **91** [9], 358–60 (1933).—The types considered are (1) general purpose, squirrel cage motor; (2) normal starting torque, low starting current, squirrel cage; (3) high starting torque, low starting current, squirrel cage; (4) high slip squirrel cage, continuous rated type; (5) high slip squirrel cage, intermittent rated type; (6) wound rotor induction motor; and (7) synchronous motor. Illustrated with charts and photographs. J.L.G.

Contribution for power and heat efficiency in ceramics and the glass industry. J. C. BREINL. *Keram. Rund.*, **41** [19], 242–44 (1933).—The paper deals with (1) the theoretical delivery of heat, (2) sources of heat, (3) gasification, (4) dry air, (5) amount of gas produced, (6) amount of additional steam, (7) waste-heat valuation, (8) steam installations with direct-fired boilers, (9) smoking flame, (10) temperature differences, and (11) gas pipes. M.V.K.

Peak loads and the monthly power bill. C. N. WITHEROW. *Brick Clay Rec.*, **83** [6], 193–96 (1933).—Peak loads are encountered in the operation of almost all industrial plants, and their elimination or control is an important factor in reducing power costs. Suggested methods of keeping costs down are listed, such as obtaining more favorable rates for off-peak service, starting heavy machinery under less than full load, spaced operation of machinery when production rates are low, etc. E.J.V.

Costs controlled by bonus plan. W. H. ROEHLKE. *Factory Management & Maintenance*, **91** [11], 446–48 (1933).—The way in which the Liquid Carbonic Co. of Chicago cuts costs with a bonus plan based on frequent time studies is explained. Illustrated by charts. J.L.G.

Fewer motions, more output. C. G. JOHNSON. *Factory Management & Maintenance*, **91** [10], 394–96 (1933).—The advantages attained from motion studies are not only increased efficiency and greater production but include relieving the fatigue of workers and promoting increased safety with fewer accidents while working. Illustrated. J.L.G.

American and Canadian producers of electrothermic and electrochemical products. *Trans. Electrochem. Soc.*, **63**, Preprint No. 4, pp. 39–44 (1933).—An attempt is made to present a complete list of the American and Canadian producers, their locations, and their products. R.H.H.P., JR.

International Congress on glass and ceramics. ANON. *Nature*, **132** [3339], 671 (1933); for abstract see *Ceram. Abs.*, **13** [2], 50 (1934). J.L.G.

BOOKS

1933 Book of A.S.T.M. Standards. ANON. **I. A.S.T.M. standards covering metallic materials.** 185 standards, 1000 pp. **II. Standards relating to nonmetallic materials.** 285 standards, 1300 pp. The two parts may be purchased at $7.50 each from the American Society for Testing Materials, 260 S. Broad St., Philadelphia, Pa. R.A.H.

Index to A.S.T.M. Standards and Tentative Standards. ANON. 124 pp. Published by the American Society for Testing Materials, Oct., 1933. R.A.H.

The Chemical Formulary. Edited by H. BENNETT. Chemical Formulary Co., Brooklyn, N. Y., 1933. 537 pp. Price $6.00. Reviewed in *Foundry*, **61** [12], 51 (1933).—Sections devoted to fuels, abrasives, and ceramic products are included in this volume. F.G.H.

Unit Processes and Principles of Chemical Engineering. JOHN C. OLSEN *et al.* 25s. Reviewed in *Nature*, **132** [3330], 298–99 (1933); see *Ceram. Abs.*, **12** [10–11], 403 (1933). J.L.G.

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